WSRC-TR-99-00010
Rev. 2

HAZARDS ANALYSIS

FOR THE

SPENT NUCLEAR FUEL L-EXPERIMENTAL FACILITY (U)

March 2001

[redacted]

Westinghouse Savannah River

Projects Engineering and Construction

Aiken, SC

SAFETY • RESPONSIBILITY • SECURITY
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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC09-96SR18500

DISCLAIMER

Key Words: Hazards Analysis
Accident Analysis
Melt and Dilute
TSF
Validation
Demonstration
Pilot Program
Retention: Lifetime

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FOR THE

SPENT NUCLEAR FUEL L-EXPERIMENTAL FACILITY (U)

March 2001

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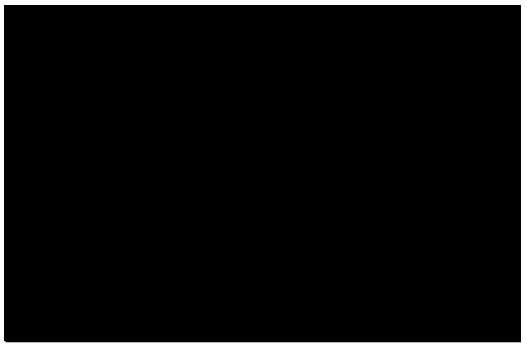

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SAFETY • RESPONSIBILITY • SECURITY
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PROJECT:	SPENT NUCLEAR FUEL TREATMENT AND STORAGE FACILITY
DOCUMENT NUMBER:	WSRC-TR-99-00010
TITLE:	HAZARDS ANALYSIS FOR THE SPENT NUCLEAR FUEL L-EXPERIMENTAL FACILITY (U)
REVISION NUMBER:	REVISION 2

SFSD REVIEW

G. F. Couture, SFSD Regulatory Programs — DATE 3/20/01

WSMS APPROVALS

A. J. Cappucci, Originator — DATE 3/20/01

E. P. Hope, Technical Reviewer — DATE 20 MARCH 2001

I. K. Paik, Manager-HAG — DATE 3/20/01

R. L. Boyleston, Manager-NMS&S/T SFS/SW — DATE 3/20/01

M. J. Hitchler, Manager-SAES — DATE

WESTINGHOUSE SAFETY MANAGEMENT SOLUTIONS

INTER-OFFICE CORRESPONDENCE

DATE: March 16, 2001

FILE NO.

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LOCATION Room 15

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SUBJECT: Delegation of Authority

I will be out of the office on Monday, March 19, through Friday, March 23. In my absence, Mark Lowman will have Delegation of Authority.

Signature on file
Ingle Paik
Hazards Analysis Group

IP:nh

TABLE OF REVISIONS

Revision	Affected Pages	Description of Revision
0	All	Original Issue
1	All	Perform Mitigated HA and Incorporate LEF HA Addendum.
2	All	Revised HA to incorporate LEF design changes and facility comments.

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

A	Anticipated
ANSI	American National Standards Institute
ARF	Airborne Release Fraction
ASME	American Society of Mechanical Engineers
BEU	Beyond Extremely Unlikely
BIO	Basis for Interim Operation
CAM	Continuous Air Monitor
CEDE	Committed Effective Dose Equivalent
DOT	Department of Transportation
DR	Damage Ratio
DU	Depleted Uranium
EDE	Effective Dose Equivalent
EPA	Environmental Protection Agency
EOPs	Emergency Operating Procedures
ERPG	Emergency Response Planning Guidelines
EU	Extremely Unlikely
FC	Functional Classification
FY	Fiscal Year
HA	Hazards Analysis
HAD	Hazard Assessment Document
HE	Hazard Evaluation
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilation, and Air Conditioning
IEEE	Institute of Electrical and Electronic Engineers
ISTC	Instrumented Storage Test Canister
ITC	Instrumented Test Canister
LEF	L – Experimental Facility
LPF	Leak Path Factor
MACCS	MelCor Accident Consequence Code System (computer code)
MAR	Material-at-Risk
MOI	Maximally Exposed Offsite Individual
MORT	Management Oversight Risk Tree
MTR	Material Test Reactor
MURR	University of Missouri Research Reactor
MWD	MegaWatt Days
NEC	National Electric Code
NFPA	National Fire Protection Association
NIM	Nuclear Incident Monitor
NPH	Natural Phenomena Hazard
OSHA	Occupational Safety and Health Act

LIST OF ACRONYMS AND ABBREVIATIONS (CONT.)

PHR	Process Hazard Review
PSM	Process Safety Management
RBOF	Receiving Basin for Offsite Fuel
RCRA	Resource Conservation and Recovery Act
RFA	Reference Fuel Assembly
RQ	Reportable Quantity
SAR	Safety Analysis Report
SFSD	Spent Fuel Storage Division
SNF	Spent Nuclear Fuel
SOPs	Standard Operating Procedures
SRL	Savannah River Laboratory
SRS	Savannah River Site
SRTC	Savannah River Technology Center
SSCs	Structures, Systems, and Components
SST/SGT	Safe Secure Trailers/Safe Guards Transporter
TPQ	Threshold Planning Quantity
TSF	Treatment and Storage Facility
TSFVT	Treatment and Storage Facility Validation Test
TQ	Threshold Quantity
U	Unlikely
WSMS	Westinghouse Safety Management Solutions
WSRC	Westinghouse Savannah River Company

DEFINITIONS

Accident - An unplanned event or sequence of events that results in undesirable consequences.

Canister - The container into which an Ingot is placed. Use of the canister facilitates handling, transportation and storage. (DOE/SNF/REP-007, DOE Spent Nuclear Fuel Glossary of Terminology, Draft, dated 5/31/96)

Cask - A container used to store or transport SNF or HLW. It provides confinement, shielding, and heat removal of the stored material.

Cropping - Removal of non-fuel components from the SNF assemblies.

Common Hazard (Standard Industrial Hazard) – A hazard routinely encountered in general industry and construction, and for which national consensus codes and/or standards exist to guide safe design and operation without the need for special analysis to define safety design and/or operational parameters. These hazards involve, but are not limited to, material and/or energy that exceed "common hazard" limits, yet the nature of the event and resulting injury to the worker are considered "common." Examples might include injuries (or death) resulting from oxygen depletion in confined spaces and some facility fires/explosions. Section 2.1.1.3 of this HA gives additional information and guidelines for screening common hazards.

Consequence - The result or effect of a release of hazardous material (radiological or chemical) usually expressed in terms of dose or exposure.

Dry Cave – A dry shielded work space within the Disassembly Basin Area of the reactor building. This space is the intended storage and monitoring area for treated SNF ingots processed from the LEF.

Depleted Uranium – Uranium containing less than 0.71 Weight Percent U-235.

Element - The fundamental unit of SNF, i.e., assembly, canned elements, or consolidated rods. The component of nuclear fuel containing the fissile material. An element may come in a wide variety of shapes and sizes. Several elements may make up an assembly. Fuel may be in a form (geometry) that, either alone, or in an assembly, can be or has been used in the reactor designated to use that form (Technical Strategy for the Treatment, Packaging, and Disposal of Aluminum-Based Spent Nuclear Fuel, dated June 1996).

Enclosure - A secondary confinement that constructed around the furnace and off-gas system.

Facility Section - A division of the facility specified to facilitate hazard identification and evaluation. Sections may be individual unit operations, individual or grouped facility systems, specific functions, and/or physical boundaries inside the facility.

Hazard – A source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel, or damage to a facility or the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation).

Hazard Analysis - A comprehensive evaluation of potential process related, natural phenomena, and external hazards that can affect the public, workers, and the environment due to single or multiple failures. Included in the analysis are hazard identification, hazard screening for common hazards, and unmitigated hazard evaluation.

Ingot – A furnace batch of treated SNF that has been allowed to solidify after the melting process is complete (Temperature of <500 degrees Celsius).

Loss of Normal Power – Loss of power from the SRS 115 Kv supply system to the L-Area Facilities, including LEF.

Material Test Reactor (MTR) - Plate and tube type spent nuclear fuel assemblies used in a majority of the foreign research reactors. A typical plate type MTR fuel has box-like housing ranging from approximately 24 to 37 inches in length with two outside housing plates and two outside fuel plates. The number of fuel elements in an assembly varies between 6 and 23, and the initial U-235 content varies between 37 gm and 780 gm per assembly. The uranium enrichment in MTR type fuel varies from just below 20 to 93.5 percent. (Fission Product Release From Spent Nuclear Fuel During Melting, WSRC-TR-97-0112, dated 5/97)

Melt and Dilute – The method of treating SNF where the SNF is melted and alloyed with depleted uranium (.02 wt. % U-235) and aluminum to produce a cast alloy ingot containing <20 wt. % U-235, packaged in a cylindrical canister, suitable for co-disposal with HLW glass logs at the national repository. The LEF is a demonstration of the Melt and Dilute concept.

Mitigate - To lessen the severity of consequences of an event.

Mitigated Consequences – A determination of consequences of an event taking credit for barriers and/or controls, which reduce the severity of the consequences.

Onsite Population - The population within the site boundary.

Prevent - To reduce the frequency of an event.

Public/Offsite Population - The population outside the SRS boundary.

Secondary Waste - Any solid or liquid waste material generated during the LEF process operations excluding the primary product, treated SNF ingots.

Standard Industrial Hazard – See Common Hazard.

Trailer Space – The existing truck trailer delivery bay area located in the 105-L Purification Wing. The trailer space is the selected location for the main equipment (e.g. furnace, off-gas system) of the proposed LEF. The trailer space also currently houses the non-operating L-Area Reactor purification cells which are separated from the trailer space by half-height concrete

shield walls. Existing non-operating purification ion exchange vessels are located in the two adjacent purification cells.

Treated SNF - The resulting U-Al alloy ingot produced by the melt and dilute SNF treatment process. It will be packaged in a canister for long term storage and monitoring in the 105-L Dry Cave. (See Ingot)

Unmitigated - Consequences of an event that have been determined with no reduction in severity and without taking credit for barriers or controls which could reduce the severity of those consequences.

EXECUTIVE SUMMARY

The Spent Nuclear Fuel (SNF) Treatment and Storage Facility (TSF) Validation Test Program was developed for the purpose of validating the basic operation and concept of the full-scale TSF Melt and Dilute process. The TSF is planned to receive, treat, package, and store aluminum-based spent nuclear fuel in the 105-L Building and L-Area for later disposal in a geologic repository (Ref. 1). The TSF Validation Test (TSFVT) will take place in the 105-L Reactor Building Purification Wing Trailer Space where the requisite equipment will be installed to form the L-Experimental Facility (LEF). The tests to be conducted in the LEF will serve to validate previous SRTC tests with unirradiated fuel and surrogate materials, and will provide operational experience with melting irradiated SNF.

A comprehensive review of hazards associated with the proposed LEF was performed to identify potential accident scenarios, to assess the risk associated with those accidents, and identify controls required to protect the public, the workers, and the environment. This effort is based upon initial design information (SFS-RSE-98-0150, Ref. 2) and was performed in accordance with the guidelines provided in DOE Standards 3009-94 (Ref. 3).

Hazardous materials and energy sources associated with the LEF were identified and are listed in the tables given in Appendix B. Following this hazard identification step, accident scenarios based on these hazardous materials and energy sources were developed. Once the accident scenarios were developed, unmitigated consequences for each of the scenarios were estimated. Scenario descriptions and unmitigated consequences are summarized in Appendix D.

Structures, systems, components (SSCs) and administrative controls that would effectively prevent or mitigate the postulated events were identified and selected in the Functional Classification Report (FCR) (Ref. 49). The FCR used information developed in the unmitigated hazard analysis, in the accident (Ref. 50) and consequence analyses (Ref. 51), and in the operational event frequency analysis (Ref. 52). The goal of the safety analysis process is to show that implementation of the credited controls would reduce the risk associated with those events such that they would not exceed evaluation guidelines. The credited controls, operational event frequencies, and the mitigated consequences of the postulated events have been incorporated into this revision to the Hazard Analysis.

The unmitigated hazard evaluation process identified a total of 113 potential hazardous event scenarios. Of the 113 event scenarios, 44 were determined to exceed the evaluation guidelines for the onsite receptors requiring further evaluation by the functional classification process and the mitigated portion of this HA. The unmitigated and mitigated consequences of these events are given in Appendix D.

For the offsite receptor, there were 7 accident scenarios for which the dose to the maximally exposed individual could exceed the Evaluation Guidelines if unmitigated. These events were further evaluated in the accident and consequences analyses and were found to be below the offsite evaluation guidelines. Therefore, per the FCR, Safety Class features and/or controls are not required.

For the onsite receptors, the 44 event scenarios exceeding the evaluation guidelines if unmitigated were further evaluated by a Functional Classification engineer as candidates for Safety Significant

functions and documented in the FCR (Ref. 49). Further evaluation was also performed in the mitigated portion of the HA. Using the credited controls for prevention, event frequencies were developed. The mitigated consequences were developed from the accident and consequence analysis taking credit for the controls identified in the FCR were applicable. All of the 44 prevented and mitigated event scenarios were determined to be below the evaluation guidelines for the onsite receptors.

Screening of technical documents available during the design phase and discussions with project personnel indicated no chemical hazards other than those listed below are introduced to the existing facility as part of this process. The only chemical hazards include the depleted uranium used to dilute the SNF in the furnace, battery acid in the forklift(s) and transport vehicle batteries, and carbon dioxide gas in portable fire suppression systems.

1.0 INTRODUCTION

The purpose of this Hazard Analysis (HA) is to identify and assess potential hazards associated with the operations of the Spent Nuclear Fuels (SNF) Treatment and Storage Facility LEF. Additionally, this HA is used to identify and assess potential hazards and specify functional attributes of SSCs for the LEF project. This HA evaluates the LEF operations that differ from those existing 105-L facility operations presently addressed by L-Reactor Facility Authorization Basis documentation.

Open Items

The design of the LEF process proposed for the 105-L Purification Wing is complete (Ref. 60). The vendor drawings (Ref. 61) and the design change packages (DCP) (Ref. 62 through 65) were reviewed against this HA and revisions were made as required. Therefore, there are no open items remaining.

1.1 SPENT NUCLEAR FUEL L-EXPERIMENTAL FACILITY DESCRIPTION

General

A validation test of the melt-dilute process using irradiated SNF is planned within the Building 105-L Purification Wing Trailer Space in L-Area. The space will be modified and outfitted accordingly to provide capability to receive, treat, and package aluminum-based Material Test Reactor (MTR) SNF assemblies. New process equipment will be installed in both the existing 105-L Purification Wing Trailer Space and in a new building immediately outside of the Trailer Space. Six (6) MTR SNF assemblies are planned for processing through the LEF, however analysis within this HA assumes up to 20 assemblies per year will be processed.

The intent of this melt and dilute validation is to validate SRTC tests with unirradiated fuels and surrogate materials and to provide operational experience with irradiated SNF. Lessons learned and experimental data acquired from the demonstration will be incorporated into the final design of the full scale TSF facility in the 105-L Building.

Process

The Melt/Dilute process seeks to convert and consolidate individual MTR SNF assemblies into a solid, treated-SNF ingot with <20% U235 enrichment. The reduction in enrichment will be achieved by adding depleted uranium. The SNF and depleted uranium will be melted in an induction furnace with aluminum added to achieve a near eutectic mixture. The molten mixture will be inductively stirred to ensure a homogenous composition. The furnace is expected to operate at ~850 degrees Celsius. The furnace used for the validation test was commercially procured and will produce a treated-SNF ingot approximately 6.75 inches in diameter by 8 inches high weighing about 20 pounds.

The batching process for delivering DU to the LEF consists of preparing individual aluminum baskets at the Savannah River Technology Center (SRTC) with approximately 1.25 kilograms (kg) of depleted uranium metal encased in aluminum (Al) per basket. A total of twenty baskets are assumed to be prepared with the DU/Al ingots. The baskets and the DU will be transported to the LEF. When scheduled for treatment, a selected stored fuel assembly from the existing L-Disassembly Basin will be placed in an aluminum basket with the DU/Al ingot in the Disassembly Basin. The basket will be transferred from the Disassembly Basin through the Transfer Canal into the Transfer Bay and placed into a transportation cask. The SNF assembly and cask will be decontaminated and loaded onto a truck to be transported from the Receiving Area Transfer Bay to the Purification Wing. The truck will not leave L-Area while enroute.

The transportation cask will be unloaded in the trailer space using the 30-ton overhead bridge crane controlled from an adjacent shielded crane aisle control room. The truck will then be removed from the trailer space and the space door will be shut. The SNF will be removed from the cask remotely by crane and charged into an induction furnace with a pre-calculated quantity of depleted uranium and aluminum. The SNF assembly and feedstock will be heated, dried, melted, and inductively stirred within the furnace. The molten alloy will be sampled through remote manipulations controlled from the Crane Aisle Control Room or Furnace Control Station, then the melt will be allowed to solidify. The solidified ingot will be removed remotely from the crucible and placed in a shielded Instrumented Storage Test Canister (ISTC) or cask located within the furnace area of the trailer space.

The ISTC/cask will remain in the trailer space until filled with 3-4 ingots, and will then be loaded onto and transported by truck to the Disassembly Basin Area. The solidified ingots stored within the ISTC will be unloaded from the truck and placed in the Disassembly Basin Dry Cave where the ISTC will be connected to monitoring equipment. The ingots created during the test will serve as initial TSF specimens and will be monitored as part of a long term monitoring program within the Dry Cave. Two ISTC casks are expected to meet LEF requirements for ingot transport to and storage within the Dry Cave. Two existing but unrelated Instrumented Test Containers (ITC) casks are presently in use monitoring existing SNF assemblies within the Dry Cave, but are not part of the LEF process.

Solidified melt samples, a portion of the offgas filtering media, and ingot(s) may be placed in a transportation cask and transported to the SRTC High Level Caves for analysis. Transportation and analysis activity outside of L-Area is not included within the scope of this HA.

Process Secondary Wastes

The LEF will generate solid secondary waste materials. Additionally, gaseous wastes in the form of noble gases and halogens from the melt process are expected to be within regulatory limits and are planned to be exhausted from the L-Reactor stack. The solid waste will typically consist of such material as HEPA filters, absorber bed type filters and used crucibles. LEF operations are not expected to generate hazardous chemical wastes or mixed wastes.

Generated secondary wastes including filtering media are expected to be transported to a disposal site; however, this transportation activity is not included within the scope of this HA. These new waste streams will be addressed by the existing facility Waste Management Program.

Offgas System

The furnace will incorporate an offgas system and enclosure ventilation system to act as a primary and secondary confinement system, respectively. The furnace offgas system will act to capture radioactive gas and particulates evolved from the furnace cavity above the melt during the melting and cool down process. The furnace enclosure provides a physical barrier around the furnace and is serviced by an enclosure ventilation system that operates as a branch of the offgas ventilation system. The furnace enclosure acts as a secondary confinement for the furnace upon accidental leakage within the primary offgas confinement system. Air within the furnace cavity and offgas system (primary confinement) will be maintained at a negative pressure relative to the air within the furnace enclosure (secondary confinement). Air within the furnace enclosure will be maintained at a negative pressure relative to the purification trailer space area. Purge air will be drawn from the furnace enclosure into the furnace cavity above the melt and into the offgas system. The offgas system consists of primary and secondary zeolite sorption beds, HEPA filters, and exhaust fans. The primary and secondary zeolite sorption beds are located within the furnace secondary confinement. The offgas system will discharge to a new duct that will join with the existing 105-L Purification Area ventilation exhaust duct. The furnace enclosure ventilation system and the primary offgas system have HEPA filters and fans that discharge through the LEF exhaust system. This branch of the system will also discharge to the existing purification ventilation exhaust duct. At least one existing EP903 fan will be operating to maintain negative pressure in the Purification Area relative to ambient external pressure and will discharge to the 105-L ventilation stack.

The secondary confinement design includes an Uninterruptible Power Supply (UPS). The UPS is design to provide six hours of ventilation in event of a loss of normal power. The UPS also provides backup power to those components required to maintain furnace secondary confinement (secondary confinement instrumentation is powered by the UPS). The UPS is a stand-alone unit containing batteries and rectifier/charging circuits and other solid state equipment to supply backup AC power to the secondary confinement system. The UPS is located in the Purification Area corridor next to the Gas Drying Equipment Area (Ref. 58).

Vendor report data states that the batteries are sealed and normally recombine all gases internally if they are charged and remain on float within the recommended charge conditions (2.37 VPC at temperatures up to 92°F). If charge conditions are exceeded, the maximum diffusion limited equilibrium concentration of hydrogen in the cabinet is 0.23%. This is well below the Lower

4.0%. With charging under normal conditions, the hydrogen concentration within the cabinet will not exceed 0.02%.

Validation Test SNF Assemblies

The SNF candidate assemblies to be melted within the LEF include both unirradiated and irradiated fuel with both high and low enrichment. To demonstrate proper operation of the furnace and support equipment, initial melts will use trial aluminum and/or depleted uranium MTR type assemblies. To validate dilution techniques, an unirradiated highly enriched Colombian IAN-R1 MTR assembly will be melted with depleted uranium. Subsequent melts will progress from low fission product inventory MTR assemblies to high fission product assemblies. The proposed order of candidate SNF assemblies is as follows (Ref. 2):

Candidate SNF	Enrichment	Burnup	Decay Time (years)
Trial DU assembly(s)	0%	0%	N/A
IAN–R1 (Colombian)	93%	0%	N/A
RU-1 (Uruguay)	19.8%	0.08%	11
RINSC (Rhode Island)	93.2%	3.2%	7
ZPRL (Taiwan)	19.8%	5-9%	12
THOR (Taiwan)	93.2%	19-26%	10
ASTRA (Austria)	93.1%	65.7%	17
MURR (Univ. of Missouri)	93.5%	22%	0.4

Candidate MTR assemblies will be stored in the L-Basin pending individual transfer to the Purification Trailer Space for melting.

1.2 HAZARDOUS MATERIAL INVENTORY

1.2.1 POTENTIAL MAXIMUM RADIONUCLIDE INVENTORY

The material processed in the LEF is planned to consist of six (6) unirradiated and irradiated assemblies received from domestic and foreign research reactors. Of the six assemblies to be processed, the MURR MTR assembly is radiologically bounding. For purposes of a conservative analysis, each SNF assembly to be processed during the validation test is assumed to be

radiologically equivalent to one MURR assembly as characterized in Table C-1 (extracted from CalcNote, S-CLC-L-00016, Ref. 50) of Appendix C. The maximum quantity of this material that is expected to be in each of the defined facility sections under reasonably worst case conditions is assumed to be that given in Table C-2 of Appendix C.

1.2.2 CHEMICAL INVENTORY

Depleted Uranium encased in aluminum is treated as a toxic chemical. The total amount of DU (U-238) is 25 kg. This quantity of depleted uranium is a chemical concern due to the toxicity of uranium should it become airborne and respirable in the event of a large fire within the building.

A review of 40 CFR 302 Table 302.4, 29 CFR 1910.119, 40 CFR 68, and 40 CFR 355 was performed. The review indicated that no chemical RQs, TQs or TPQs exists for uranium metal. However, 40 CFR 302 Appendix B to Table 302.4 (the appendix radionuclide table to the 302.4 chemical table) does indicate a value of 0.1 Ci as the final RQ for uranium isotopes 234, 235, and 238. Footnotes in Appendix B to Table 302.4 direct that any conflict in RQ values between the radionuclide table (Appendix B to Table 302.4) and the chemical table (Table 302.4) should be resolved by selecting the RQ value from either table which is the lowest value. Since there is no chemical RQ listed in Table 302.4 for uranium metal, the radionuclide RQ value from Appendix B to Table 302.4 was selected as the chemical RQ by default. Therefore, the final chemical RQ value from 40 CFR 302 for the uranium isotope 238 is 0.1 Ci.

Using the specific activity of U-238 (3.36E-7 Ci/g) as a good approximation of the specific activity of depleted uranium, allows conversion of the 0.1 Ci RQ to kilograms. This yields an equivalent RQ for depleted uranium of approximately 298 kg. The LEF depleted uranium inventory (25 kg) is well below this value. Therefore, per the methodology outlined in Reference 8 for toxic materials, this quantity of DU is considered to be a common industrial hazard and further analysis is not required.

No other chemicals have been identified for use in the LEF operations. It is assumed that there will be no hazardous chemical inventory within the facility other than small quantities of battery acid in the UPS batteries and the forklift and transport truck batteries. Carbon dioxide gas is also contained within portable fire extinguishers. A 78% zinc-bromide solution is also presently being used within the two shielded viewing windows between the crane aisle control room and the trailer space in the 105-L Purification Wing. Additionally, although not a part of the LEF operations, contaminated ion exchange resin contained within the eight (8) purification deionizer vessels is presently stored in the purification cells adjacent to the trailer space.

1.3 ASSUMPTIONS

The intent of these assumptions is to establish a baseline upon which this HA can be performed. The assumptions will not restrict design modifications but simply identify those features used in the analysis. However, any departure from these assumptions subsequent to completion of this HA must be re-evaluated. The following assumptions were used:

A. Due to the variety of SNF to be received and processed, the radionuclide inventory for any fuel assembly processed by the LEF will be modeled by the inventory quantity represented by the University of Missouri Research Reactor (MURR) SNF Assembly (150 MWD with 150 day cooling). This assembly is used as a conservative bounding assembly for all postulated release scenarios. The radionuclide inventory of this SNF assembly is listed in Appendix C, Table C-1.

B. The melt and dilute process operates as a batch process with each batch having a radionuclide inventory of one MURR assembly as listed in Assumption A above.

C. The cask used to transport the SNF to the Purification Trailer Space will contain an aluminum basket with an aluminum encased depleted uranium ingot and one fuel assembly in the Purification Trailer Space prior to unloading. The cask will also contain contaminated disassembly basin water.

D. Solidified melt samples, a portion of the offgas filtering media, and ingots may be placed in a transportation cask and transported to the SRTC High Level Caves for analysis. Transportation and analysis activity outside of L-Area is not included within the scope of this HA.

E. For safety analysis purposes, responsibility for SNF assemblies and ingots will be retained by the LEF during transport between the Transfer Bay, Purification Wing Trailer Space and the Dry Cave (all within L-Area). For transportation of LEF radioactive materials out of L-area (Assumption C above), LEF responsibility is transferred to the carrier when the cask lid is bolted and the cask is mounted on the transport trailer and is ready for transport. Transportation and analysis activity of LEF materials outside of L-Area is not included within the scope of this HA.

F. Deleted.

G. Existing Purification Cell deionizer vessels (8) are assumed to contain Amberlite 120 or 400 resin or equivalent, with a radioactive inventory after de-deuterization as follows (WSRC-TR-94-0590, Ref. 20):

Tritium	120 Ci / deionizer
C-14	20 Ci / deionizer
Cs-137	2 Ci / deionizer
Sr-90	3.2 Ci /deionizer
Alpha Emitter	0.1 Ci /deionizer

The dose which results from a fire consuming all 8 deionizer vessels is assumed to be equivalent to the dose resulting from 1 MURR consumed by fire (derived from Ref. 20 and RADScreen, Ref. 28). See Table E-2 in Appendix E.

H. The furnace is considered "in operation" when the metal temperature in the crucible is above 500°C and fission products are off-gassing from the SNF.

I. There will be no more than 5 MURR worth of treated or untreated SNF in the Furnace Area (and Trailer Space) at any given time. This Assumption is based on 4 treated MURR ingots awaiting transportation with 1 MURR assembly arriving by truck or in the furnace.

J. The furnace crucible is constructed of graphite. The crucible uses a new steel crucible liner for each melt. Clamshell heaters are placed above the crucible and are primarily used for insulation. When they are operated, the clamshell heaters will heat the crucible and minimize cesium plate-out on the crucible walls. Crucibles will not be packaged with the ingots in the ISTC, and will be disposed of as secondary waste.

K. For the purposes of conservatively analyzing events associated with the off-gas filters in the unmitigated analysis, all of the cesium contained in each furnace batch is released during a normal melting cycle. For the mitigated analysis, only 80% is released (Ref. 50).

L. For the purposes of conservatively analyzing events associated with the ingots in the unmitigated analysis, none of the cesium contained in the melt is given off and therefore remains in the ingot when the molten material solidifies. For the mitigated analysis, 20% of the cesium is retained (Ref. 50).

M. For the purposes of conservatively analyzing events associated with the off-gas filters in the Unmitigated Hazard Analysis, the furnace off-gas Cesium absorber bed becomes fully loaded.

N. For the purposes of conservatively analyzing events associated with the off-gas system, the radioactive material release to the off-gas system is equivalent to 10% of each MURR batch. Maximum expected inventory in the offgas system prior to filter change-out = 10% x 5 MURR batches = 0.5 MURR

O. Sample volume and activity is equivalent to 1.5 % (0.015) of a MURR.

P. Deleted.

Q. Deleted.

R. Hazardous chemicals in excess of TQs, TPQs, or RQs will not be used in the LEF process.

S. All noble gases and halogens given off during the melting process are released from the stack to the environment.

T. The existing SNF assemblies located in the Dry Cave which are not associated with the LEF process are equivalent to 0.5 MURR each in radiological inventory for MAR calculations.

U. In an unmitigated hazard analyses where no shielding or remote operation is credited, the dose due to direct radiological exposure of facility workers to SNF assemblies, ingots and loaded filters would tend to bound the Onsite 1 receptor category with a consequence of "High" for the majority of events. This would overshadow the event dose component due to respirable uptake. As such, in this analysis, the direct radiation exposure dose component is disregarded in most events to allow the dose component due to respirable release uptake

to be emphasized for the Onsite 1 receptor. To address the hazard associated with direct radiation exposure, at least one loss/lack of shielding event (event category E-4) is included in each facility section Hazard Evaluation table (Appendix D).

V. In regard to conservative frequency analysis for the unmitigated analysis, up to 20 assemblies may be processed per year. Each melt batch requires 8 hours with the furnace energized. A furnace failure rate was assumed at 2E-6 failures/hr (Ref. 16). Crane equipment failure frequency is based on 8 hours per day operation with 4 days of activity per melt process, and a component failure rate of approximately 1.0E-5 failures/hr (Ref. 16). In general, worker error operating cranes or other equipment is assumed to be >1.0E-2 occurrences/demand (Ref. 14).

W. For the mitigated analysis, the processing of 20 SNF assemblies is assumed. Event frequencies are based on the calculated event frequencies in Reference 52.

X. Loss of normal power in the LEF involves losing ventilation flow resulting in the loss of differential pressure between primary and secondary containment, which is a required safety function (Ref. 56). Cooling water to the furnace will be lost during a loss of normal power event resulting in a longer cool down period (5 vs. 3 hours) to reach the melt solidification temperature (Ref. 57).

Y. With the UPS operating ventilation and differential pressure between primary and secondary containment would be maintained.

Z. The LEF control building outside of Building 105-L is assumed to be designed to PC-2 requirements for NPH events to protect the UPS powered circuitry from detrimental II/I interactions.

AA. No hazardous chemicals will be used in the LEF process except for depleted uranium, which is considered to be chemically toxic.

BB. The batching process for delivering DU to the LEF consists of preparing individual aluminum baskets at the Savannah River Technology Center (SRTC) with approximately 1.25 kilograms (kg) of depleted uranium metal encased in aluminum (Al) per basket. A total of twenty baskets are assumed to be prepared with the DU/Al ingots.

2.0 HAZARDS ANALYSIS

This section describes the Hazard Analysis (HA) performed for the LEF at the design phase. The HA is the initial step in analytical evaluation of accident conditions for this project. It provides a systematic analysis of potential process-related, natural phenomena, and external hazards that can affect the public, the workers, and the environment due to single or multiple failures. This analysis considers the potential for both equipment failure and human error.

The Hazards Analysis Team is typically represented by such functions as safety documentation development, hazard and accident analyses, risk and consequence analyses, facility

operations/engineering, safety system/functional classification, Technical Safety Requirements development, material technology research, and design engineering.

In performing the HA, the Team provides a thorough, predominantly qualitative evaluation of the spectrum of risks to the public and facility workers due to accidents involving the identified hazards. The analysis consists of two basic activities: Hazard Identification and Hazard Evaluation (HE). DOE-STD-3009-94 (Ref. 3) requires that the hazard analysis comprehensively identify potential events, event initiators, and dominant scenarios; estimate their frequencies and consequences; and present the results in a risk matrix. Gross estimates of consequences and frequencies are performed in the hazard analysis such that attention is focused on those scenarios that are of greatest concern or pose the highest risk.

2.1 HAZARDS ANALYSIS METHODOLOGY

Hazard Analysis comprises the initial series of steps conducted within the guidelines of the Safety Documentation Integrated Work Process (Ref. 21). This section presents the hazards analysis methodology used in identifying and characterizing hazards associated with the LEF and in performing a systematic evaluation of the postulated hazardous event scenarios involved. Results of this HA are presented in Section 2.2.

2.1.1 HAZARD IDENTIFICATION

Hazard Identification is a comprehensive and systematic process by which all known hazards (hazardous materials and energy) associated with the facility are identified, recorded, and screened by a team of individuals representing the stakeholder organizations. In the HA, screening is performed to eliminate material/energy types and quantities that are considered "common hazards".

Hazard Identification is divided into three steps: (1) division of the facility into "sections", (2) Facility walkdowns, and (3) screening for common hazards.

2.1.1.1 Division of the Facility

Partitioning of the facility into "sections" facilitates hazard identification and evaluation. These sections may be individual unit operations, individual or grouped facility systems, specific function(s), and/or physical boundaries inside the facility. When deemed appropriate, a single general hazard facility-section may cover common cause events that could involve more than one facility-section (e.g. facility fire and earthquake).

2.1.1.2 Facility Information Gathering and Walkdowns

Facility information gathering is a key element in the process of identifying hazardous materials and energy sources that are currently known or which may be associated with each facility HA section, particularly at the conceptual design stage of a project. This information gathering

process includes reviews of current design documentation, system drawings, functional performance requirements, procedures, etc. in the context of Hazard Identification, and direct interactions with the designers responsible for the specific sections of the facility. In addition, if the design involves a modification to an existing facility, it is generally helpful to perform a physical walkdown of the facility as well to aid in the identification of potential hazards. The HA team uses a hazards checklist or legend (an example is given in Table A-1) that lists generic facility hazards as a useful aid in conducting hazard identification. This checklist is based on the DOE Management Oversight Risk Tree (MORT) methodology (Ref. 5).

Using the results of the information gathering and physical walkdowns, the HA team creates a listing of all expected radiological and chemical hazards. Hazard Identification Tables (see Appendix B) are typically used to document the results of the Hazard Identification process and are developed for each facility section.

2.1.1.3 Screening of Common Hazards

The third step in the Hazard Identification process is the screening of common hazards. These are defined as hazards that are routinely encountered and accepted in general industry and construction, and for which national consensus codes and/or standards (e.g., OSHA and transportation safety) exist to guide safe design and operation. In accordance with DOE-STD-3009-94 (Ref. 3), hazard evaluations of industrial hazards and routinely accepted hazards are not included. Standard industrial hazards and routinely accepted hazards are evaluated only to the degree that they could act as initiators and contributors to events that result in radiological and chemical release events. The following characteristics are used to determine hazards that are considered standard industrial hazards and routinely accepted hazards:

- The hazard is controlled by OSHA regulations or national consensus standards (e.g., ASME, ANSI, NFPA, IEEE, NEC), where these standards are adequate to define special safety requirements, unless in quantities or situations that initiate events with serious impact to the public or workers.

- Hazards such as noise, electricity, flammable materials, welding operations, small quantities of chemicals that would likely be found in homes or general retail outlets, and hazardous materials transported on the open road in DOT specified containers are considered to be common hazards encountered in everyday life.

Examples of common hazards include:

- specific materials (e.g., lead and asbestos) that have their own control program,
- thermal energy sources (potential for burns),
- electrical shock hazards,
- gas cylinders transported and stored in DOT configuration and within design limits,
- personnel pinches, trips, falls, slips, etc.,

- confined space hazards,
- hazards typically found in office areas.

Chemical Screening

Chemicals that require hazard evaluation are those that are present in amounts exceeding the threshold planning quantity (TPQ) listed in *The List of Extremely Hazardous Substances and Reportable Quantities* (TPQ), 40 CFR 355 (Ref. 23); the threshold quantity (TQ) listed in *Risk Management Programs for Chemical Accidental Release Prevention*, 40 CFR 68 (Ref. 24); the reportable quantity (RQ) listed in the *List of Hazardous Substances and Reportable Quantities*, 40 CFR 302.4 (Ref. 25) or the TQ listed in *Process Safety Management (PSM) of Highly Hazardous Chemicals*, 29 CFR 1910 (Ref. 26).

The screening of the chemical inventory will be conducted as follows:

a) Eliminate a chemical if it is not present in quantities greater than a RQ, TPQ or TQ established for that material.

b) Eliminate a chemical if it has been previously analyzed to be insignificant hazards and there is nothing to indicate that a more detailed evaluation is required (e.g., the material is present in greater than end-user quantities).

c) Eliminate the chemical if one or more of the following is valid:
   - The material is identified as a sample.
   - The material is identified as part of the radionuclide inventory.
   - The material is used in a laboratory setting and in laboratory scale quantities. Materials whose maximum amount at a given location or segment was under ten pounds were designated as being a laboratory quantity.

d) Propose elimination of the chemical if it satisfies one or more of the following criteria:
   - The material is commonly used in industry and/or by the general public:
     - Materials such as vehicle fuel and common industrial solvents are normally screened. These materials can be event initiators for hazardous materials in close proximity, and they were considered in the hazard evaluation.
   - The material is a true solid (e.g., not a finely divided powder) under normal circumstances and does not present an airborne concern (e.g., lead shielding is not an airborne concern)
   - The material does not and cannot cause harm via the inhalation pathway from an acute exposure.
   - The material has a vapor pressure of $\leq$ 0.5 mm Hg at 25 degrees C and an ERPG-2 or equivalent of $\geq$ 1 ppm.

Practicing basic safety in the workplace provides protection against industrial hazards and routinely accepted hazards. Such hazards are formally and systematically treated by the following programmatic elements:

- WSRC Procedure Manual 8Q (Ref. 6) defines basic site-wide safety policies and minimum requirements. This procedure manual is augmented by detailed rules and procedures developed by departments and facilities for activities within their areas of responsibility. The manual requires compliance with DOE Orders and OSHA regulations, at a minimum, for industrial safety.

- The operating philosophy at the Savannah River Site is that the safety and health of employees is the first and utmost priority. Policies are implemented at the facility level through facility-specific procedures.

- During the design phase of SRS facilities or modifications to existing facilities, various design reviews contribute to industrial hazard identification. Application of the Management Oversight Risk Tree (MORT) process and information from past operating reports also contribute to the hazard identification process.

- During facility operation, several programs ensure timely identification of industrial hazards. These programs include OSHA compliance reviews, routine safety audits and periodic safety inspections, incident investigations (formal reviews and assessments of any unsafe situation or incident), annual safety program reviews, monthly safety meetings, safety suggestion programs, and the SRS Quality Assurance program.

The HA team examines each identified hazard for each section based on material/energy types and quantities using the general guidance given above and considers its potential contribution as an initiator for events involving release of radiological material, hazardous energy, or hazardous chemicals.

If the identified hazard does not meet the appropriate screening criteria for identification as a common hazard, the hazard is not considered common and is carried forward to the Hazard Evaluation.

2.1.2 HAZARD EVALUATION

The Hazard Evaluation (HE) constitutes the primary focal point of the HA. Hazards are characterized in the context of actual or anticipated facility operations and processes by considering feasible release mechanisms (or events), estimating initiating event frequency, and estimating consequences of the release. The purpose of Hazard Evaluation is to ensure a comprehensive assessment of facility hazards and to focus attention on those events that pose the greatest risk to the public, onsite workers, and the environment.

The Hazard Evaluation (HE) is performed in accordance with the requirements of DOE-STD-3009-94 (Ref. 3), WSRC Procedure Manual 11Q (Ref. 7), and the Hazard Analysis Methodology Manual (Ref. 8).

Authorization Basis Guidance Document 007-06, Analytic Methods (Ref. 9), requires that "All hazardous events, with the exception of sabotage, will be identified in the Hazards Analysis (unmitigated). These events are the bases for subsequent analyses such as mitigated Hazard Analyses, Accident Analyses, Emergency Preparedness Hazard Analyses, and Fire Hazard Analysis.

In this regard, the scope of Hazard Evaluation includes:

- All aspects of facility process and operation.
- Natural phenomena (e.g. earthquakes, tornadoes, straight-line winds), external events (e.g. aircraft and vehicular impact), and nuclear criticality (where applicable).
- Consideration of the entire spectrum of possible events for a given hazard in terms of both frequency and consequence levels.
- Hazards addressed by other programs and regulations (e.g. PSM, OSHA, RCRA, DOT, EPA) if loss of control of the hazard will result in a release.

The scope of Hazard Evaluation does not include:

- Willful acts, such as sabotage.
- Hazardous events that meet the screening criteria given in Section 2.1.1.3.

Detailed information regarding hazardous material and energy sources in the context of facility section and/or whole facility operations is the basis for specific release events. Event categorization, identification of event cause(s), assignment of initiating event/event frequency and unmitigated/mitigated consequence level, and final consequence determination are tasks performed during Hazard Evaluation.

Information related to Hazard Evaluation is collected and organized in "Hazard Evaluation Tables." These tables are useful as a guide for performing Hazard Evaluation, and they provide an effective format for documenting Hazard Evaluation results. A separate Hazard Evaluation Table is constructed for each facility section. Information in these tables includes:

- Event Number
- Event Category (E-1 through E-7)
- Postulated Event Description (including location and hazard source)
- Causes
- Preventive Features (Design and Administrative)
- Initiating Event Frequency Level (unmitigated and mitigated)
- Mitigative Features (Design and Administrative)
- Consequence Level estimates for On-Site and Off-Site individuals (unmitigated and mitigated)
- Risk Level (unmitigated and mitigated)

For an unmitigated analysis, estimated values are provided in the columns pertaining to Initiator Frequency Level, Unmitigated Consequence Level and Unmitigated Risk Level within the HE Table. Additionally, any preventive and mitigative controls which may be available within the facility are listed in their respective HE Table columns; however, no credit is applied to the available controls during the unmitigated hazard analysis. Unmitigated HE Tables will typically list "TBD" (To Be Determined) in columns pertaining to Mitigated Initiator Frequency Level, Mitigated Consequence Level and Mitigated Risk Level until such time as the mitigated analysis is complete.

For the mitigated analysis, in addition to the unmitigated data, credited Preventive and Mitigative Features are indicated by underlining within their respective HE Table columns and the calculated Mitigated Frequency Level, Mitigated Consequence Level and Mitigated Risk Level values resulting from the credited controls are also provided. Using this format, the HE Table facilitates ease of comparison between unmitigated and mitigated risk for each event.

Additional detail and pertinent methodology information regarding each of the Hazard Evaluation Table columns are provided in the following sections.

2.1.2.1 Event Number

Events are numbered to provide each with a sequential reference. The numbering system is chosen such that facility section is identified mnemonically. For example, facility section identified as "Furnace Area" would be abbreviated as "FA" in the Hazard Evaluation table. Events associated with the pump house would then be numbered FA-1, FA-2, etc.

2.1.2.2 Event Category

Events are categorized according to the nature of the postulated release mechanism. A standard list of event categories, based on those given in Appendix C of DOE/TIC-11603 (Ref. 10), is used. This categorization scheme is used simply to label the various types of postulated events and plays no part in the subsequent identification of preventive or mitigative controls. The event categories are as follows:

- E-1 Fire
- E-2 Explosion
- E-3 Loss of Containment/Confinement
- E-4 Direct Radiological/Chemical Exposure
- E-5 Nuclear Criticality
- E-6 External Events
- E-7 Natural Phenomena

Events are categorized according to the event description rather than the event cause. For example, a facility fire might be a postulated event that is caused by an earthquake or some other natural phenomena. This event would fall under category E-1 (Fire) rather than E-7 (Natural Phenomena). Table A-2 gives additional information regarding event categories and associated hazardous material and energy sources.

2.1.2.3 Postulated Event Description

A brief description of a postulated event is given in this column of the Hazard Evaluation Tables. The event description clearly defines the nature of the event. It includes the type of event, its location, hazard source, affected system(s) or equipment, and any pertinent operating characteristics.

Using the results of the Hazard Identification process as a basis, the HA team develops event scenarios for each facility section wherever a potential exists for a release of hazardous energy and/or material. The scenarios cover the entire spectrum of possible events for a given hazard; from small consequence events, for which procedures or equipment may be credited in providing adequate protection, to reasonable worst-case conditions. Unlike "worst-case," "reasonable worst-case" does not necessarily consider every parameter in its most unfavorable state. For example, if a toxic material is normally handled as a liquid at room temperature during processing, a reasonable worst-case release does not have to consider a spill with the liquid at 130°F.

2.1.2.4 Causes

A cause specifically states the failure, error, operational, and/or environmental condition that could initiate the postulated event. Causes need to be clearly identified to support frequency evaluation. This list typically identifies the major contributors and is not necessarily an exhaustive list of every possible cause. The Hazard Identification Tables are used as a guide in developing specific causes for release events.

2.1.2.5 Initiating Event Frequency Level

Event frequency evaluation is a qualitative or quantitative process that involves assigning a frequency level to the initiators of each event in the Hazard Evaluation Tables. Frequency levels and descriptions are summarized in the Frequency Evaluation Levels (Table A-3) which are based on DOE-STD-3009-94 (Ref. 3).

The frequency level determination is based on the event's cause(s) and may be either qualitative or quantitative. Sources of frequency information include generic initiator database information, engineering calculations, analyses for other facilities, and judgement by experts. The frequency level is recorded in the Hazard Evaluation Tables according to the lettering scheme given in Table A-3.

Erring in the conservative direction from best-estimate values accommodates uncertainties in frequency levels. This practice is particularly important when an event frequency is just below the

next highest frequency level. For example, the HA team considers the sources of frequency-related information, the methods used to evaluate that information, and the uncertainty associated with the evaluation process. With this information, the team might collectively decide to call an event "Anticipated" if the event has been estimated to have an initiator frequency at the high end of the "Unlikely" level.

2.1.2.6 Event Frequencies for the Mitigated HA

For the mitigated HA, credit is taken for preventive features identified in the Functional Classification Report (Ref. 49), frequency calculations performed for the LEF Project (Ref. 52), and the Fire Risk Analysis (FHA) (Ref. 53) to determine overall event frequencies. The frequency level is recorded in the Hazard Evaluation Tables according to the lettering scheme given in Table A-3.

2.1.2.7 Unmitigated Consequence Level

Event consequences are documented by specifying the impact on the receptors (described below). Any potential impact of consequences on other systems is also documented in this column of the Hazard Evaluation Tables.

For unmitigated HA purposes, consequences are defined as the dose or exposure at specified receptor locations based upon unmitigated release of hazardous material. Consequences are a function of the type and characteristics of the hazard, the quantity of hazardous material released, the release mechanism, relative location of the release, and any relevant transport characteristics. Consequences are determined from (1) simple source term calculations, (2) existing safety documentation, and/or (3) qualitative assessment. The HA team utilizes its discretion, expertise, and knowledge of facility hazards to select one or more of the above methods appropriate for consequence determination. Unlike frequency levels that cover two orders of magnitude, consequence levels sometimes span less than one order of magnitude. Thus, a more refined effort may be required to determine the appropriate consequence level for a given event and receptor. As in frequency evaluation, the consequence should err in the conservative direction, especially for those events with consequences at the high end of a given level.

Consequences are evaluated at various receptor locations to assess health and environmental effects associated with the postulated event. Table A-4 gives the consequence levels for radiological releases and their relationship to specified receptor locations, using maximally exposed individual at each receptor location. Receptors are:

Offsite — Offsite receptors are the public or everyone outside the site boundary. The nearest Site boundary point is 9.16 miles from Building 105-L.

Onsite-1 — Onsite-1 receptors are workers inside the facility. This category of receptors includes those workers in the immediate area of the hazard ("proximate workers") and those workers in the same room or building associated with the hazard ("facility workers") who may not be aware of the hazardous condition.

Onsite-2 Onsite-2 receptors are workers outside the facility but within the site boundary. For evaluation purposes, these workers are located outside the last possible barrier from the hazard and at the worst possible location. Doses are calculated for the Onsite 2 receptor at a distance of 100 meters.

These receptors are consistent with those used in the SRS Functional Classification Methodology (Ref. 11).

The Hazard Evaluation Tables should provide, for each of the postulated release events, the impact of the event on the three receptors. This information is documented in the column labeled "Consequence Level" of the Hazard Evaluation Tables.

2.1.2.8 Mitigated Consequence Level

For mitigated HA purposes, consequences are defined as the dose or exposure at specified receptor locations based upon mitigated release of hazardous material. Consequences are a function of the type and characteristics of the hazard, the quantity of hazardous material released, the release mechanism, relative location of the release, and any relevant transport characteristics. The mitigated consequence levels were derived from the LEF accident analysis (Ref. 50) and the LEF consequence analysis (Ref. 51). The accident and consequence analysis was performed for a set of bounding accidents, which included:

- Crucible Failure Explosion
- Rapid Steam Generation
- Furnace Extreme Overheating Transient
- Fire During Transport
- Furnace area Fire
- Storage Area Fire
- Full Facility Fire

All of the operational events (excluding criticality and radiation exposure) are assumed bounded by these events. Consequences from exposure to radiation events were derived from the LEF shielding analysis (Ref. 54). Criticality events were determined to have a frequency of Beyond Extremely Unlikely (Ref. 55) as well as certain external events (aircraft and helicopter crashes). Therefore, consequences from these events were determined to negligible.

For natural phenomena events such as earthquake, tornado, or high wind the Purification Trailer Space and the Control building are qualified as a PC-2 structures. In addition, there are no unsatisfactory seismic II/I conditions existing in the Purification Trailer Space and the Control building. Therefore, natural phenomena events were treated as Beyond the Design Basis events for the Mitigated HA. The existing Authorization Basis (Ref. 45) concluded that lightning

strikes on the 105-L Building would not result in a release of material stored within the structure. Lightning strikes on transport vehicles were considered to be credible.

2.1.2.9 Risk Ranking

Using event frequency and consequence levels, the HA team "bins" events in frequency-consequence space to assess relative risk in accordance with DOE STD-3009-94 (Ref. 3) and the WSRC Hazard Analysis Methodology Manual (Ref. 8). The objective of risk binning is to focus attention on those events that pose the greatest risk to the public, onsite receptors, and the environment. Higher risk events might be candidates for additional analysis and/or functional classification evaluation.

Tables A-5, A-6, and A-7 are risk binning matrices for the three receptor locations considered in the HA (i.e., offsite, onsite-1, and onsite-2). In each of these tables, a rectangular matrix defines bins in frequency-consequence space. Each bin is uniquely numbered, but numbering is for identification purposes only (i.e., risk severity is not proportional to the magnitude of the bin label).

Table A-5 is the risk-binning matrix for offsite receptors. The crosshatched bins, (i.e., 1, 2, 3, 4, 5, and 7), represent risk that exceeds the offsite radiological and/or chemical evaluation guidelines for Functional Classification. Events falling into these bins typically require further evaluation by a Functional Classification engineer as candidates for Safety Class functions. In DOE-STD-3009-94 (Ref. 3) terminology, these events are considered "unique," or "situations of major concern," with sufficiently high risk that individual examination is needed by accident analysis.

The three lightly shaded bins in Table A-5, (i.e., 6, 8, and 9), fall below the Functional Classification evaluation guidelines, yet per Reference 3, these events are considered "situations of concern" that yield a subset of "representative" events needing further examination. Representative events bound a number of similar events of lesser risk (i.e., the worst fire for a number of similar fires). At least one event from each of the event types (i.e., fires, explosions, etc.) is considered representative, however representative events are examined only to the extent that they are not bounded by unique events.

Table A-6 is the risk binning matrix for the onsite-1 receptor(s) located anywhere inside the facility with the hazardous release or hazardous condition. The crosshatched bins, (i.e., 1, 2, 4, 5, and 7), represent risk that exceeds the onsite radiological and/or chemical evaluation guidelines for Functional Classification. Events falling into these bins typically require further evaluation by a Functional Classification engineer as candidates for Safety Significant functions.

Table A-7 is the risk binning matrix for the onsite-2 receptor(s) located somewhere outside the facility. The crosshatched bins, (i.e., 1, 2, 4, 5, and 7), represent risk that exceeds the onsite radiological and/or chemical evaluation guidelines for Functional Classification. Events falling into these bins typically require further evaluation by a Functional Classification engineer as candidates for Safety Significant functions.

The Hazard Evaluation Tables provides, for each of the postulated release events, a bin number representing risk at each receptor location.

2.1.2.10 Identification of Potential Controls

Preliminary identification of potential preventive and mitigative features begins during the Hazard Identification process. Potential preventive and mitigative controls are listed in Appendix D in the Hazard Evaluation Tables for each postulated event. It is from this list that the controls needed to prevent or mitigate hazardous events are selected.

Accident and consequence analysts and functional classification engineers have utilized this Hazards Analysis to select and subsequently credit preventive and mitigative controls to lessen the probability and/or severity of the postulated accidents listed herein. The credited controls have been incorporated into this document providing mitigated analysis results.

A preventive feature is any feature that is relied upon to act to reduce the frequency of an initiating cause that could result in the release of hazardous material or energy to an unwanted location. Preventive features might include engineered features (e.g. structures, systems, components, etc.) and administrative controls (e.g. procedures, policies, programs, etc.), operating individually or in combination. The Hazard Evaluation Tables are formatted such that a distinction is made between administrative and engineered (design) features. Preventive features are assumed to be operable prior to an event and are not required to be operable during the event or post event.

Mitigative features are any features that are relied upon to reduce the consequences associated with the release of hazardous material or energy. Mitigative features are those which are assumed to be operable during an event or after the event, and are not required to be operating prior to the event initiation. Therefore, mitigative features must be capable of withstanding the environment of the event. As with preventive features, mitigative features might include engineered features or administrative controls operating individually or in combination. The Hazard Evaluation Tables are be formatted to make the distinction between administrative and engineered (design) features.

Control selection was performed according the methodology given in the Functional Classification Manual (Ref. 11) and is documented in Reference 49.

2.2 LEF HAZARD ANALYSIS RESULTS

As discussed in Section 2.1, the HA consists of two basic analytical activities: hazard identification and hazard evaluation. This section provides an in-depth discussion of the results from the performance of these activities for the LEF.

The LEF HA team included, on an as-required basis, representatives from the following disciplines:

- Hazard Analysis
- Risk Management/Analysis
- Projects Engineering
- Facilities Operations/Engineering
- SRTC/Strategic Materials Technology
- Bechtel/Design Engineering

- Fire Protection
- Criticality Analysis

2.2.1 HAZARD IDENTIFICATION

In accordance with the methodology given in Section 2.1.1, and to ensure completeness, hazards associated with the LEF were systematically identified by listing hazardous materials, energy sources, and their locations in tables. Screening was performed to eliminate material/energy types and quantities that are considered "common hazards." Hazard Identification was divided into three steps; 1) division of the facility into "sections," 2) facility/information walkdowns, and 3) identification of common hazards.

Division of the L-Experimental Facility

To facilitate hazard identification and evaluation, the LEF was divided into six (6) sections. These sections were based upon the physical locations of the various rooms or areas, their contents and functions, and flow of material in the building. The sections for the LEF are as follows (with acronym used in the Hazard Evaluation Table):

1. Furnace Area (FA) (Purification Wing Trailer Space)

2. Crane Aisle Control Room (upper level Purification Wing) and UPS Corridor (corridor at Elevation 0 in Purification Wing) (CC)

3. Furnace Control Station (FC) (external bldg.)

4. Receiving Area Transfer Bay (TB)

5. Dry Cave Area (DC)

6. Transportation (TR) (between Receiving Area Transfer Bay and Furnace Area)

Note: Activities that are normally performed within the Disassembly Basin and addressed by existing L-Area Authorization Basis documentation are not duplicated in this Hazards Analysis.

Facility Walkdowns

Although the LEF was in the design stage, and modifications to Building 105-L Purification Wing Trailer Space had not begun, the HA Team performed a physical walkdown of the area as an aid in identifying potential hazards. SRTC Strategic Materials Technology experts also provided a walkthrough of its bench model induction coil furnace located in SRTC. Documents associated with the proposed functions of the LEF were reviewed with the HA Team. This "paper walkdown" included review of facility-related documents included in Section 4.0 References of this document.

Screening of Common Hazards

Using the guidance provided in Section 2.1.1, members of the HA team examined each identified hazard for each section to determine its potential contribution to events resulting in release of radiological material or hazardous energy.

If the identified hazard did not meet the appropriate screening criteria for identification as a common hazard, it was not considered common and was carried forward through the complete Hazard Evaluation step.

Results of Hazard Identification

Tables B-1 through B-6 of Appendix B, Hazard Identification Tables, list all identified hazards (those not screened as standard industrial or routinely accepted according to criteria in Section 2.1.1) and corresponding locations for each section in the LEF. Since no chemicals were identified by facility personnel for use in the LEF, (except truck battery acid, the crane control room shielded window zinc-bromide solution, and CO_2) it was assumed that there would be no hazardous chemical inventory in the facility. A chemical mixing study was not performed as part of the Hazard Identification process.

Several of the hazards listed in the Hazard Identification Tables may not exist in the 105-L Building Purification Trailer Space at this time and were assumed to be those that would exist after installation of the LEF process. These assumptions were based on information gathered from conceptual design documents, interviews with facility representatives, and analyst experience.

2.2.2 HAZARD EVALUATION

One of the purposes of the Hazard Evaluation at the design phase is to identify the potential events that could impact the offsite and two onsite receptors. The results from the Hazard Evaluation are then used for preliminary functional classification of the Structure, Systems, and Components in the LEF.

Determination of the event frequency and the level of consequence for each of the postulated events were performed using unmitigated initiating events and unmitigated material release.

For each of the postulated events, frequencies were estimated using such information sources as the generic frequency database (Ref. 12), natural phenomena frequency data (Ref. 13), human error database development (Ref. 14), engineering judgement, or existing safety documentation.

For the unmitigated hazards analysis, it is useful to envision a hypothetical "working" facility in the open, such as in a green field or a parking lot, with no protective aspects which might normally be expected to prevent or mitigate potential radioactive releases. This hypothetical facility may be expected to have conservatively high accident frequencies, consequences and risk, which serve as bounding reference points from which to establish the necessary controls to mitigate or prevent the accidents.

In the unmitigated analysis, to determine the consequence level of each event, a semi-quantitative assessment is performed. In this assessment, estimates of the potential radiological dose were based on the amount of hazardous material released that subsequently becomes airborne. The airborne source term (ST) were estimated by the following five component linear equation involving: Material-at-Risk (MAR), Damage Ratio (DR), Airborne Release Fraction (ARF), Respirable Fraction (RF) and Leak Path Factor (LPF).

$$ST = MAR \times DR \times ARF \times RF \times LPF$$

The MAR is the material inventory within the facility section and was taken from Table C-2 in Appendix C. The material assumed to be affected is represented by the product MAR x DR for each event, where MAR is the inventory available to be acted upon, and the DR is the fraction of the MAR actually impacted. The product of ARF x RF represents the fraction of the material impacted that becomes airborne and is respirable. The LPF is assumed to be 1.0 for unfiltered releases. Details and assumptions used in the derivation of source terms and unmitigated consequences for the LEF postulated events are included in Appendix E.

Using these event frequencies and consequences, the HA Team "binned" the postulated events according to the matrices given in Tables A-5, A-6, and A-7. The goal was to identify those events that pose the greatest risk to the public, onsite workers, and the environment. The results of the Hazard Evaluation process for the LEF are given in the tables provided in Appendix D (Tables D-1 through D-6) of this report.

Following the development of the LEF accident and consequence analyses and the Functional Classification Report, event frequencies and mitigated consequences were determined. The results of the mitigated hazard analysis are documented in Appendix D.

Hazardous Chemical Release Consequence

No chemicals have been identified for use in the process operation of the LEF. Chemicals identified to be associated with the LEF exist in small quantities. They include depleted uranium for SNF dilution, battery acid (sulfuric acid) in the lead-acid batteries of the transport truck, a 78% zinc-bromide solution within the crane control room shielded windows, and CO_2 contained within portable fire suppression equipment. Of these chemicals, no quantities were found to exceed RQ,

TQ or TPQs. These small chemical quantities do not exceed Site guidelines and may represent only a very localized hazard if released.

3.0 CONCLUSIONS

A comprehensive review of hazards associated with the Spent Nuclear Fuel LEF was performed to identify potential accident scenarios. To determine the unmitigated and mitigated risk of accidents, a Hazards Analysis was performed. The hazard evaluation process identified a total of 113 potential hazardous event scenarios. The unmitigated and mitigated consequences of these events are given in Appendix D.

For the offsite receptor, there were 7 accident scenarios for which the dose to the maximally exposed individual exceeded the Evaluation Guidelines if unmitigated. Detailed accident and consequence analysis has demonstrated that the consequences from the 7 accidents are below the SRS Evaluation Guidelines. For the onsite worker, there are 44 event scenarios for which the dose to the maximally exposed individual exceeded the Evaluation Guidelines if unmitigated. The mitigated hazard analysis demonstrated that taking credit for preventors and mitigators drives the consequences below the Evaluation Guidelines.

For the onsite receptors, the 44 event scenarios exceeding the evaluation guidelines if unmitigated were further evaluated as candidates for Safety Significant functions and documented in the FCR (Ref. 49). Further evaluation was also performed in the mitigated portion of the HA. Using the credited controls for prevention from the FCR, the LEF frequency calculations, and the FRA, event frequencies were developed. The mitigated consequences were developed from the accident and consequence analysis taking credit for the controls identified in the FCR were applicable. All of the 44 prevented and mitigated event scenarios were determined to be below the evaluation guidelines for the onsite receptors. A summary of the results of the mitigated HA is presented in Table E-6 of Appendix E.

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APPENDIX A

METHODOLOGY TABLES

Table A-1 Hazardous Material/Energy Checklist

Hazard Group	Specific Hazardous Material/Energy Source	
Electrical	Battery banks Cable runs Diesel units Electrical equipment Hot plates Heaters High voltage Locomotive, electrical Motors	Pumps Power tools Switchgear Service outlets, fittings Transformers Transmission lines Underground wiring Wiring
Thermal	Bunsen burner/ Hot plates Electrical equipment Furnaces Heaters	Steam lines Welding torch Exothermic reactions
Friction	Belts Bearings Fans	Gears Motors Power tools
Pyrophoric Material	Pu and U metal	
Spontaneous Combustion	Nitric acid and organics	
Combustibles	Combustible materials	
Chemical Reactions	Uncontrolled chemical reactions	
Open Flame	Bunsen burners Torches	Pilot lights Gas Welding
Flammables	Flammable gases Flammable liquids	Flammable mixtures
Explosives	Explosive gases Hydrogen/Tritium	Propane Explosive chemicals
Potential	Gas bottles Gas receivers	Pressure vessels Steam headers and lines
Kinetic	Fans Pumps	Motors Rotating machinery
Non-facility Events	Explosion	Fire
Radiological Material	Radiological material	
Fissile Material	Fissile material	
Non-Ionizing Radiation	Non-ionizing radiation	
Ionizing Radiation	Fissile material Radiography equipment	Radioactive material Radioactive sources
Hazardous Material	Alkali metals Asphyxiants Biologicals Carcinogens	Oxidizers Corrosives Toxics
Natural Phenomena	Earthquake Flood Lightning Rain	Snow, ice Freezing weather Straight wind Tornado
Vehicles in Motion	Airplane Helicopter Train	Truck/Car Forklift
Crane	Crane	

Table A-2 Event Categories & Relationship to Hazardous Material and Energy Sources

Event Category	Event Category Description	Hazard Energy and Material Groups
E-1	Fire	Electrical Thermal Friction Pyrophoric material Spontaneous combustion Open flame Flammables Combustibles Chemical Reactions
E-2	Explosion	Potential (pressure) Explosive materials Chemical Reactions
E-3	Loss of Containment or Confinement	Radiological Material Hazardous Material
E-4	Direct Radiological/Chemical Exposure	Ionizing radiation sources Non-ionizing radiation sources Chemicals
E-5	Nuclear Criticality	Fissile Material
E-6	External Hazards	Non-facility Events Vehicles in Motion Crane Kinetic
E-7	Natural Phenomena	Natural Phenomena

Table A-3 Initiating Event Frequency Evaluation Levels

Event Frequency Code	Description	Estimated Annual Frequency of Occurrence ($year^{-1}$)
Anticipated (A)	Accidents that may occur several times during the life cycle of the facility (accidents that commonly occur).	$f > 10^{-2}$
Unlikely (U)	Accidents that are not anticipated to occur during the life cycle of the facility. Natural phenomena of this probability class include the following: Uniform Building Code-level earthquake, 100-year flood, maximum wind gust, etc.	$10^{-2} \geq f > 10^{-4}$
Extremely Unlikely (EU)	Accidents that will probably not occur during the life cycle of the facility. This class includes the design basis accidents.	$10^{-4} \geq f > 10^{-6}$
Beyond Extremely Unlikely (BEU)	All other accidents.	$f \leq 10^{-6}$

Table A-4 Radiological Consequence Evaluation Levels for Hazard Receptors.

Consequence Level (Abreviation) ↓	Receptor (considered location) Offsite	Onsite 1 (Inside Facility)	Onsite 2 (Outside Facility)
High (H)	> 25.0 rem	(PROXIMATE WORKER) prompt worker fatality, acute injury that is immediately life threatening or permanently disabling (FACILITY WORKER) radiological consequences>100 rem or radiological material quantity exceeds Hazard Category 3 threshold (per DOE-STD-1027)	> 100.0 rem or prompt worker fatality, acute injury that is immediately life threatening or permanently disabling
Moderate (M)	5.0 < C ≤ 25.0 rem	(PROXIMATE WORKER) serious injury, no immediate loss of life, no permanent disabilities, hospitalization required (FACILITY WORKER) radiological consequences 25 < C ≤ 100 rem	25.0 < C ≤ 100.0 rem or serious injury, no immediate loss of life, no permanent disabilities, hospitalization required
Low (L)	0.5 < C ≤ 5.0 rem	(PROXIMATE WORKER) minor injuries, no hospitalization (FACILITY WORKER) radiological consequences 5 < C ≤ 25 rem	5.0 < C ≤ 25.0 rem or minor injuries, no hospitalization
Negligible (N)	≤ 0.5 rem	(PROXIMATE WORKER) <Low (FACILITY WORKER) ≤ 5.0 rem	≤ 5.0 rem or < Low

Table A-5. Risk Binning Matrix in Frequency-Consequence Space - Offsite Receptors

Frequency → / Consequence ↓	Beyond Extremely Unlikely $\leq 10^{-6}$/yr	Extremely Unlikely $10^{-6} < f \leq 10^{-4}$/yr	Unlikely $10^{-4} < f \leq 10^{-2}$/yr	Anticipated $> 10^{-2}$/yr
High Radiological > 25 rem Chemical > ERPG-2	10	7	4	1
Moderate Radiological 5 < C ≤ 25 rem Chemical ERPG-1 < C ≤ ERPG-2		8	5	2
Low Radiological 0.5 < C ≤ 5 rem Chemical PEL-TWA < C ≤ ERPG-1		9	6	3
Negligible Radiological ≤ 0.5 rem Chemical ≤ PEL-TWA	11	12		

Key:

- **Risk Bins 1, 2, 3, 4, 5, 7**
  * Exceed Functional Classification evaluation guidelines for offsite receptors
  * "Unique" events, individual examination needed

- **Risk Bins 6, 8, 9**
  * "Representative" events, examined to the extent that they are not bounded by unique events, at least one bounding event from the each event category (fires, explosions, etc.)

Table A-6. Risk Binning Matrix in Frequency-Consequence Space - Onsite 1 Receptor (Inside Facility)

Frequency → Consequence ↓	**Beyond Extremely Unlikely** $\leq 10^{-6}$ /yr	**Extremely Unlikely** $10^{-6} < f \leq 10^{-4}$ /yr	**Unlikely** $10^{-4} < f \leq 10^{-2}$ /yr	**Anticipated** $> 10^{-2}$ /yr
High (PROXIMATE WORKER) prompt worker fatality, acute injury that is immediately life threatening or permanently disabling (FACILITY WORKER) Radiological: radiological consequences>100 rem or radiological material quantity exceeds Hazard Category 3 threshold (per DOE-STD-1027) Chemical: uniform distribution of total release exceeds ERPG-3	**10**	**7**	**4**	**1**
Moderate (PROXIMATE WORKER) serious injury, no immediate loss of life, no permanent disabilities, hospitalization required (FACILITY WORKER) Radiological: radiological consequences 25 < C ≤ 100 rem Chemical: uniform distribution of total release ERPG-2 < C ≤ ERPG-3		**8**	**5**	**2**
Low (PROXIMATE WORKER) minor injuries, no hospitalization (FACILITY WORKER) Radiological: radiological consequences 5 < C ≤ 25 rem Chemical: uniform distribution of total release ERPG-1 < C ≤ ERPG-2		**9**	**6**	**3**
Negligible (PROXIMATE WORKER) < Low (FACILITY WORKER) Radiological: ≤ 5 rem Chemical: ≤ ERPG-1	**11**	**12**		

Key:

- **Risk Bins 1, 2, 4, 5, 7**
  * Exceed Functional Classification evaluation guidelines for onsite receptors

Table A-7. Risk Binning Matrix in Frequency-Consequence Space - Onsite 2 Receptor (Outside Facility)

Frequency → Consequence ↓	**Beyond Extremely Unlikely** $\leq 10^{-6}$ /yr	**Extremely Unlikely** $10^{-6} < f \leq 10^{-4}$ /yr	**Unlikely** $10^{-4} < f \leq 10^{-2}$ /yr	**Anticipated** $> 10^{-2}$ /yr
High Radiological: > 100 rem Chemical: > ERPG-3 Any Hazard: prompt worker fatality, acute injury that is immediately life threatening or permanently disabling		7	4	1
Moderate Radiological: 25 < C ≤ 100 rem Chemical: ERPG-2 < C ≤ ERPG-3 Any Hazard: serious injury, no immediate loss of life, no permanent disabilities, hospitalization required	10	8	5	2
Low Radiological: 5 < C ≤ 25 rem Chemical: ERPG-1 < C ≤ ERPG-2 Any Hazard: minor injuries, no hospitalization		9	6	3
Negligible Radiological: ≤ 5 rem Chemical: ≤ ERPG-1 Any Hazard: < low	11	12		

Key:

- **Risk Bins 1, 2, 4, 5, 7**
  * exceed Functional Classification evaluation guidelines for onsite receptors

APPENDIX B

HAZARD IDENTIFICATION TABLES

Table B-1 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Furnace Area

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																		
	Electrical																			Thermal								Friction								
	Battery Banks (BB)	Cable Runs (CB)	Diesel Units (DU)	Electrical Equipment (EE)	Hot Plates (HP)	Heaters (HT)	High Voltage (HV) [> 600 V]	Locomotive, electrical (LE)	Motors (MT)	Pumps (PM)	Power Tools (PT)	Switchgear (SG)	Service Outlets, fittings (SO)	Transformers (TF)	Transmission Lines (TL)	Underground Wiring (UW)	Wiring (WR)	Other	Bunsen Burner, Hot Plate (BR)	Electrical Equipment (EE)	Furnaces (FR)	Heaters (HT)	Steam Lines (SL)	Welding Torch (WT)	Exothermic Reactions (ER)	Other	Belts (BL)	Bearings (BE)	Fans (FN)	Gears (GE)	Motors (MT)	Power Tools (PT)	Other
Area																																			
Furnace Area (Trailer Space)		X	X	X					X		X		X				X			X	X							X		X	X	X	

X = Refers to the hazards considered applicable

Table B-1 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Furnace Area

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
							Open Flame					Flammables				Explosives					Potential					Kinetic							
	Pyrophoric (Pu & U Metal) (PU)	Pyrophoric (Other)	SC* (Nitric Acid and Organics) (HN)	SC* (Other)	Combustible Materials (CB)	Uncontrolled Chem. Reactions (CH)	Bunsen Burners (BR)	Torches (WT)	Pilot Lights (PL)	Gas Welding (GW)	Other	Flammable Gases (FG)	Flammable Liquids (FL)	Flammable Mixtures (FA)	Other	Explosive Gas (EG)	Hydrogen/Tritium (HZ)	Propane (PP)	Explosive Chemicals (EC)	Other	Gas Bottles (GB)	Gas Receivers (GR)	Pressure Vessels (PV)	Steam Headers/Lines (ST)	Other	Fans (FN)	Pumps (PM)	Motors (MT)	Rotating Machinery (RO)	Other	Non-Facility Event (Explosion) (EX)	Non-Facility Event (Fire) (FI)	Non-Facility Event (Other) (OT)
Area																																	
Furnace Area (Trailer Space)					X								X[3]			X[4]					X[1]		X[2]					X	X		X	X	X

*SC = Spontaneous Combustion

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Outside Purification Wing, CO_2 bottle in Control Station

2 Pneumatic Line

3 Truck fuel

4 Truck battery hydrogen

Table B-1 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Furnace Area

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
				Ionizing Rad.					Hazardous Materials								Natural Phenomena									Vehicles in Motion							
	Radiological Material (RM)	Fissile Material (FM)	Non-Ionizing Radiation (NI)	Fissile Material (FM)	Radiography Equipment (RE)	Radioactive Materials (RM)	Radioactive Sources (RS)	Other	Alkali Metals (AM)	Asphyxiants (AS)	Biological (BI)	Carcinogens (CA)	Oxidizers (OX)	Corrosives (CO)	Toxics (TX)	Other	Earthquake (EQ)	Flood (FD)	Lightning (LT)	Rain (RN)	Snow, Ice (SN)	Freezing Weather (FW)	Straight Wind (SW)	Tornado (TO)	Other	Airplane (AP)	Helicopter (HL)	Train (TN)	Truck/Car (TR)	Forklift/Lift Truck (FK)	Other	Crane/Hoist (CR)
Area																																	
Furnace Area (Trailer Space)	X	X		X		X		X[1]						X[2]	X[3]		X	X	X	X		X	X	X		X	X		X	X		X

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Deionizer pressure vessels,resins, filters, and evaporator

2 Truck battery acid

3 Depleted Uranium

Table B-2 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Crane Aisle Control Room

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
	Electrical																		Thermal								Friction							
	Battery Banks (BB)	Cable Runs (CB)	Diesel Units (DU)	Electrical Equipment (EE)	Hot Plates (HP)	Heaters (HT)	High Voltage (HV) [> 600 V]	Locomotive, electrical (LE)	Motors (MT)	Pumps (PM)	Power Tools (PT)	Switchgear (SG)	Service Outlets, fittings (SO)	Transformers (TF)	Transmission Lines (TL)	Underground Wiring (UW)	Wiring (WR)	Other	Bunsen Burner, Hot Plate (BR)	Electrical Equipment (EE)	Furnaces (FR)	Heaters (HT)	Steam Lines (SL)	Welding Torch (WT)	Exothermic Reactions (ER)	Other	Belts (BL)	Bearings (BE)	Fans (FN)	Gears (GE)	Motors (MT)	Power Tools (PT)	Other
Area																																	
Crane Aisle Control Room	X[3]	X		X					X			X	X	X[1]			X			X		X	X[2]					X	X		X	X	

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Rectifiers

2 Heater Steam Line

3 Batteries in UPS Corridor

Table B-2 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Crane Aisle Control Room

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
							Open Flame					Flammables				Explosives					Potential					Kinetic							
	Pyrophoric (Pu & U Metal) (PU)	Pyrophoric (Other)	SC* (Nitric Acid and Organics) (HN)	SC* (Other)	Combustible Materials (CB)	Uncontrolled Chem. Reactions (CH)	Bunsen Burners (BR)	Torches (WT)	Pilot Lights (PL)	Gas Welding (GW)	Other	Flammable Gases (FG)	Flammable Liquids (FL)	Flammable Mixtures (FA)	Other	Explosive Gas (EG)	Hydrogen/Tritium (HZ)	Propane (PP)	Explosive Chemicals (EC)	Other	Gas Bottles (GB)	Gas Receivers (GR)	Pressure Vessels (PV)	Steam Headers/Lines (ST)	Other	Fans (FN)	Pumps (PM)	Motors (MT)	Rotating Machinery (RO)	Other	Non-Facility Event (Explosion) (EX)	Non-Facility Event (Fire) (FI)	Non-Facility Event (Other) (OT)
Area																																	
Crane Aisle Control Room					X												X				X[1]		X[2]	X	X[3]	X		X	X		X	X	X

*SC = Spontaneous Combustion

X = Refers to the hazards considered applicable

FOOTNOTES:

1 CO_2 bottle

2 Hydraulic Lines

3 Breathing Air Manifolds

Table B-2 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Crane Aisle Control Room

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																		
				Ionizing Rad.					Hazardous Materials								Natural Phenomena									Vehicles in Motion										
	Radiological Material (RM)	Fissile Material (FM)	Non-Ionizing Radiation (NI)	Fissile Material (FM)	Radiography Equipment (RE)	Radioactive Materials (RM)	Radioactive Sources (RS)	Other	Alkali Metals (AM)	Asphyxiants (AS)	Biological (BI)	Carcinogens (CA)	Oxidizers (OX)	Corrosives (CO)	Toxics (TX)	Other	Earthquake (EQ)	Flood (FD)	Lightning (LT)	Rain (RN)	Snow, Ice (SN)	Freezing Weather (FW)	Straight Wind (SW)	Tornado (TO)	Other	Airplane (AP)	Helicopter (HL)	Train (TN)	Truck/Car (TR)	Forklift/Lift Truck (FK)	Other	Crane/Hoist (CR)
Area																																			
Crane Aisle Control Room														X			X		X				X	X		X	X							

X = Refers to the hazards considered applicable

Table B-3 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Furnace Control Station

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
	Electrical																	Thermal								Friction							
	Battery Banks (BB)	Cable Runs (CB)	Diesel Units (DU)	Electrical Equipment (EE)	Hot Plates (HP)	Heaters (HT)	High Voltage (HV) [> 600 V]	Locomotive, electrical (LE)	Motors (MT)	Pumps (PM)	Power Tools (PT)	Switchgear (SG)	Service Outlets, fittings (SO)	Transformers (TF)	Transmission Lines (TL)	Underground Wiring (UW)	Wiring (WR)	Other	Bunsen Burner, Hot Plate (BR)	Electrical Equipment (EE)	Furnaces (FR)	Heaters (HT)	Steam Lines (SL)	Welding Torch (WT)	Exothermic Reactions (ER)	Other	Belts (BL)	Bearings (BE)	Fans (FN)	Gears (GE)	Motors (MT)	Power Tools (PT)	Other
Area																																	
Furnace Control Station	X[2]	X		X		X			X	X	X	X	X	X[1]			X			X		X						X	X		X	X	

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Rectifiers

2 UPS Batteries

Table B-3 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Furnace Control Station

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
							Open Flame					Flammables				Explosives					Potential					Kinetic							
	Pyrophoric (Pu & U Metal) (PU)	Pyrophoric (Other)	SC* (Nitric Acid and Organics) (HN)	SC* (Other)	Combustible Materials (CB)	Uncontrolled Chem. Reactions (CH)	Bunsen Burners (BR)	Torches (WT)	Pilot Lights (PL)	Gas Welding (GW)	Other	Flammable Gases (FG)	Flammable Liquids (FL)	Flammable Mixtures (FA)	Other	Explosive Gas (EG)	Hydrogen/Tritium (HZ)	Propane (PP)	Explosive Chemicals (EC)	Other	Gas Bottles (GB)	Gas Receivers (GR)	Pressure Vessels (PV)	Steam Headers/Lines (ST)	Other	Fans (FN)	Pumps (PM)	Motors (MT)	Rotating Machinery (RO)	Other	Non-Facility Event (Explosion) (EX)	Non-Facility Event (Fire) (FI)	Non-Facility Event (Other) (OT)
Area																																	
Furnace Control Station					X																X[1]					X	X	X	X		X	X	X

*SC = Spontaneous Combustion

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Outside Purification Wing, CO2 bottle in Control Station

Table B-3 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Furnace Control Station

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
				Ionizing Rad.					Hazardous Materials								Natural Phenomena									Vehicles in Motion							
	Radiological Material (RM)	Fissile Material (FM)	Non-Ionizing Radiation (NI)	Fissile Material (FM)	Radiography Equipment (RE)	Radioactive Materials (RM)	Radioactive Sources (RS)	Other	Alkali Metals (AM)	Asphyxiants (AS)	Biological (BI)	Carcinogens (CA)	Oxidizers (OX)	Corrosives (CO)	Toxics (TX)	Other	Earthquake (EQ)	Flood (FD)	Lightning (LT)	Rain (RN)	Snow, Ice (SN)	Freezing Weather (FW)	Straight Wind (SW)	Tornado (TO)	Other	Airplane (AP)	Helicopter (HL)	Train (TN)	Truck/Car (TR)	Forklift/Lift Truck (FK)	Other	Crane/Hoist (CR)
Area																																	
Furnace Control Station																	X	X	X	X	X	X	X	X		X	X		X	X		X[1]

X = Refers to the hazards considered applicable

FOOTNOTES:

1 External Crane

Table B-4 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Receiving Area Transfer Bay

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
	Electrical																	Thermal								Friction							
	Battery Banks (BB)	Cable Runs (CB)	Diesel Units (DU)	Electrical Equipment (EE)	Hot Plates (HP)	Heaters (HT)	High Voltage (HV) [> 600 V]	Locomotive, electrical (LE)	Motors (MT)	Pumps (PM)	Power Tools (PT)	Switchgear (SG)	Service Outlets, fittings (SO)	Transformers (TF)	Transmission Lines (TL)	Underground Wiring (UW)	Wiring (WR)	Other	Bunsen Burner, Hot Plate (BR)	Electrical Equipment (EE)	Furnaces (FR)	Heaters (HT)	Steam Lines (SL)	Welding Torch (WT)	Exothermic Reactions (ER)	Other	Belts (BL)	Bearings (BE)	Fans (FN)	Gears (GE)	Motors (MT)	Power Tools (PT)	Other
Area																																	
Transfer Bay		X		X		X		X	X	X	X		X	X			X			X		X	X				X	X	X	X	X	X	

X = Refers to the hazards considered applicable

Table B-4 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Receiving Area Transfer Bay

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
							Open Flame					Flammables				Explosives					Potential					Kinetic							
	Pyrophoric (Pu & U Metal) (PU)	Pyrophoric (Other)	SC* (Nitric Acid and Organics) (HN)	SC* (Other)	Combustible Materials (CB)	Uncontrolled Chem. Reactions (CH)	Bunsen Burners (BR)	Torches (WT)	Pilot Lights (PL)	Gas Welding (GW)	Other	Flammable Gases (FG)	Flammable Liquids (FL)	Flammable Mixtures (FA)	Other	Explosive Gas (EG)	Hydrogen/Tritium (HZ)	Propane (PP)	Explosive Chemicals (EC)	Other	Gas Bottles (GB)	Gas Receivers (GR)	Pressure Vessels (PV)	Steam Headers/Lines (ST)	Other	Fans (FN)	Pumps (PM)	Motors (MT)	Rotating Machinery (RO)	Other	Non-Facility Event (Explosion) (EX)	Non-Facility Event (Fire) (FI)	Non-Facility Event (Other) (OT)
Area																																	
Transfer Bay					X								X[2]			X[1]								X	X[3]	X	X	X	X		X	X	X

*SC = Spontaneous Combustion

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Battery hydrogen

2 Truck fuel

3 Compressed air lines

Table B-4 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Receiving Area Transfer Bay
(Page 3 of 3)

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
				Ionizing Rad.					Hazardous Materials								Natural Phenomena									Vehicles in Motion							
	Radiological Material (RM)	Fissile Material (FM)	Non-Ionizing Radiation (NI)	Fissile Material (FM)	Radiography Equipment (RE)	Radioactive Materials (RM)	Radioactive Sources (RS)	Other	Alkali Metals (AM)	Asphyxiants (AS)	Biological (BI)	Carcinogens (CA)	Oxidizers (OX)	Corrosives (CO)	Toxics (TX)	Other	Earthquake (EQ)	Flood (FD)	Lightning (LT)	Rain (RN)	Snow, Ice (SN)	Freezing Weather (FW)	Straight Wind (SW)	Tornado (TO)	Other	Airplane (AP)	Helicopter (HL)	Train (TN)	Truck/Car (TR)	Forklift/Lift Truck (FK)	Other	Crane/Hoist (CR)
Area																																	
Transfer Bay	X	X		X		X								X[1]			X	X	X	X	X	X	X	X		X	X	X	X	X		X

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Battery acid

Table B-5 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Dry Cave Area

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																														
	Electrical																		Thermal								Friction						
	Battery Banks (BB)	Cable Runs (CB)	Diesel Units (DU)	Electrical Equipment (EE)	Hot Plates (HP)	Heaters (HT)	High Voltage (HV) [> 600 V]	Locomotive, electrical (LE)	Motors (MT)	Pumps (PM)	Power Tools (PT)	Switchgear (SG)	Service Outlets, fittings (SO)	Transformers (TF)	Transmission Lines (TL)	Underground Wiring (UW)	Wiring (WR)	Other	Bunsen Burner, Hot Plate (BR)	Electrical Equipment (EE)	Furnaces (FR)	Heaters (HT)	Steam Lines (SL)	Welding Torch (WT)	Exothermic Reactions (ER)	Other	Belts (BL)	Bearings (BE)	Fans (FN)	Gears (GE)	Motors (MT)	Power Tools (PT)	Other
Area																																
Ingot Storage and Monitoring		X		X							X		X				X			X										X	

X = Refers to the hazards considered applicable

Table B-5 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Dry Cave Area

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																														
							Open Flame						Flammables				Explosives					Potential					Kinetic							
	Pyrophoric (Pu & U Metal) (PU)	Pyrophonic (Other)	SC* (Nitric Acid and Organics) (HN)	SC* (Other)	Combustible Materials (CB)	Uncontrolled Chem. Reactions (CH)	Bunsen Burners (BR)	Torches (WT)	Pilot Lights (PL)	Gas Welding (GW)	Other	Flammable Gases (FG)	Flammable Liquids (FL)	Flammable Mixtures (FA)	Other	Explosive Gas (EG)	Hydrogen/Tritium (HZ)	Propane (PP)	Explosive Chemicals (EC)	Other	Gas Bottles (GB)	Gas Receivers (GR)	Pressure Vessels (PV)	Steam Headers/Lines (ST)	Other	Fans (FN)	Pumps (PM)	Motors (MT)	Rotating Machinery (RO)	Other	Non-Facility Event (Explosion) (EX)	Non-Facility Event (Fire) (FI)	Non-Facility Event (Other) (OT)
Area																																
Ingot Storage and Monitoring	X				X							X[2]	X[2]			X[1]														X	X	X

*SC = Spontaneous Combustion

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Hydrogen from fuel corrosion

2 Flammable storage cabinet

Table B-5 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Dry Cave Area

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																															
				Ionizing Rad.					Hazardous Materials								Natural Phenomena									Vehicles in Motion							
	Radiological Material (RM)	Fissile Material (FM)	Non-Ionizing Radiation (NI)	Fissile Material (FM)	Radiography Equipment (RE)	Radioactive Materials (RM)	Radioactive Sources (RS)	Other	Alkali Metals (AM)	Asphyxiants (AS)	Biological (BI)	Carcinogens (CA)	Oxidizers (OX)	Corrosives (CO)	Toxics (TX)	Other	Earthquake (EQ)	Flood (FD)	Lightning (LT)	Rain (RN)	Snow, Ice (SN)	Freezing Weather (FW)	Straight Wind (SW)	Tornado (TO)	Other	Airplane (AP)	Helicopter (HL)	Train (TN)	Truck/Car (TR)	Forklift/Lift Truck (FK)	Other	Crane/Hoist (CR)
Area																																
Ingot Storage and Monitoring	X	X		X		X											X	X	X	X			X	X		X	X			X		

X = Refers to the hazards considered applicable

Table B-6 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Transportation

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																														
	Electrical																			Thermal								Friction						
	Battery Banks (BB)	Cable Runs (CB)	Diesel Units (DU)	Electrical Equipment (EE)	Hot Plates (HP)	Heaters (HT)	High Voltage (HV) [> 600 V]	Locomotive, electrical (LE)	Motors (MT)	Pumps (PM)	Power Tools (PT)	Switchgear (SG)	Service Outlets, fittings (SO)	Transformers (TF)	Transmission Lines (TL)	Underground Wiring (UW)	Wiring (WR)	Other	Bunsen Burner, Hot Plate (BR)	Electrical Equipment (EE)	Furnaces (FR)	Heaters (HT)	Steam Lines (SL)	Welding Torch (WT)	Exothermic Reactions (ER)	Other	Belts (BL)	Bearings (BE)	Fans (FN)	Gears (GE)	Motors (MT)	Power Tools (PT)	Other
Area																																	
Truck Transport	X		X	X				X	X	X	X			X	X	X	X			X						X[1]	X	X	X	X	X	X	

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Engines, Exhaust

Table B-6 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Transportation

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																														
							Open Flame					Flammables				Explosives					Potential					Kinetic							
	Pyrophoric (Pu & U Metal) (PU)	Pyrophonic (Other)	SC* (Nitric Acid and Organics) (HN)	SC* (Other)	Combustible Materials (CB)	Uncontrolled Chem. Reactions (CH)	Bunsen Burners (BR)	Torches (WT)	Pilot Lights (PL)	Gas Welding (GW)	Other	Flammable Gases (FG)	Flammable Liquids (FL)	Flammable Mixtures (FA)	Other	Explosive Gas (EG)	Hydrogen/Tritium (HZ)	Propane (PP)	Explosive Chemicals (EC)	Other	Gas Bottles (GB)	Gas Receivers (GR)	Pressure Vessels (PV)	Steam Headers/Lines (ST)	Other	Fans (FN)	Pumps (PM)	Motors (MT)	Rotating Machinery (RO)	Other	Non-Facility Event (Explosion) (EX)	Non-Facility Event (Fire) (FI)	Non-Facility Event (Other) (OT)
Area																																
Truck Transport					X								X[1]			X[2]					X					X	X	X	X		X	X	X

*SC = Spontaneous Combustion

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Truck fuel

2 Battery hydrogen

Table B-6 Hazard Energy Sources, Materials, and Their Locations for the SNF L-Experimental Facility - Transportation

Location (identifier for system, sub-system, or operational feature in this facility section)	Hazard Energy Sources and Materials																																
				Ionizing Rad.					Hazardous Materials								Natural Phenomena									Vehicles in Motion							
	Radiological Material (RM)	Fissile Material (FM)	Non-Ionizing Radiation (NI)	Fissile Material (FM)	Radiography Equipment (RE)	Radioactive Materials (RM)	Radioactive Sources (RS)	Other	Alkali Metals (AM)	Asphyxiants (AS)	Biological (BI)	Carcinogens (CA)	Oxidizers (OX)	Corrosives (CO)	Toxics (TX)	Other	Earthquake (EQ)	Flood (FD)	Lightning (LT)	Rain (RN)	Snow, Ice (SN)	Freezing Weather (FW)	Straight Wind (SW)	Tornado (TO)	Other	Airplane (AP)	Helicopter (HL)	Train (TN)	Truck/Car (TR)	Forklift/Lift Truck (FK)	Other	Crane/Hoist (CR)
Area																																	
Truck Transport	X	X		X		X								X[1]	X[2]		X	X	X	X	X	X	X	X		X	X	X	X	X		X

X = Refers to the hazards considered applicable

FOOTNOTES:

1 Battery acid

2 Depleted Uranium

APPENDIX C

FACILITY INVENTORY

Table C-1 – MURR Assembly (150 MW-Day, 150 Day Cooling) Material Inventory

Radionuclide	Activity (Ci)
Ag-108	4.05E-08
Ag-108m	4.65E-07
Ag-110	5.07E-03
Ag-110m	4.47E-01
Ag-111	2.81E-04
Am-241	2.04E-01
Am-242	6.66E-05
Am-242m	6.69E-05
Am-243	2.48E-05
As-77	5.52E-09
Ba-137m	5.70E+02
Ba-140	2.33E+01
Bi-212	1.97E-07
C-14	6.63E-07
Cd-113m	7.17E-02
Cd-115	1.17E-07
Cd-115m	7.38E-01
Ce-139	2.32E-04
Ce-141	2.80E+03
Ce-143	5.16E-07
Ce-144	1.23E+04
Cm-242	7.14E-02
Cm-243	9.30E-06
Cm-244	4.59E-04
Cs-132	7.71E-08
Cs-134	2.06E+02
Cs-135	2.13E-03
Cs-136	8.43E-02
Cs-137	6.03E+02
Eu-152	5.55E-02
Eu-154	7.35E+00
Eu-155	1.08E+01
Eu-156	7.59E-01
Gd-153	4.23E-03
H-3	2.48E+00
I-129	1.45E-04
I-131	9.96E-02
I-132	5.49E-04
In-114	1.33E-05
In-114m	1.39E-05
In-115m	5.37E-05
Kr-85	6.99E+01
La-140	2.68E+01
Mo-99	2.84E-04
Nb-93m	2.77E-04
Nb-94	2.42E-07

Radionuclide	Activity (Ci)
Nb-95	2.17E+04
Nb-95m	1.40E+02
Nd-147	2.21E+00
Np-235	6.75E-06
Np-237	6.06E-04
Np-238	9.18E-07
Np-239	4.26E-05
Pa-231	4.17E-08
Pa-233	6.00E-04
Pa-234m	2.29E-05
Pb-212	1.97E-07
Pd-107	6.66E-05
Pm-145	7.11E-06
Pm-146	6.21E-03
Pm-147	1.90E+03
Pm-148	1.91E+00
Pm-148m	3.60E+01
Pm-149	1.16E-05
Pm-151	4.74E-09
Po-212	1.26E-07
Po-216	1.98E-07
Pr-143	3.93E+01
Pr-144	1.23E+04
Pr-144m	1.73E+02
Ra-224	1.98E-07
Rb-86	1.15E-02
Rb-87	1.55E-07
Rh-102	1.39E-03
Rh-103m	2.43E+03
Rh-105	2.28E-07
Rh-106	8.01E+02
Rn-220	1.98E-07
Ru-103	2.46E+03
Ru-106	8.01E+02
Sb-124	2.51E-01
Sb-125	3.57E+01
Sb-126	5.70E-04
Sb-126m	1.29E-03
Sb-127	3.54E-05
Se-79	3.93E-03
Sm-145	2.74E-06
Sm-151	4.41E+00
Sm-153	1.28E-06
Sn-117m	1.36E-04
Sn-119m	4.89E-01
Sn-121	3.51E-03

Radionuclide	Activity (Ci)
Sn-121m	4.53E-03
Sn-123	1.52E+01
Sn-125	2.51E-03
Sn-126	1.29E-03
Sr-89	6.45E+03
Sr-90	6.03E+02
Tb-160	8.01E-02
Tb-161	5.91E-07
Tc-99	8.25E-02
Tc-99m	2.75E-04
Te-123m	2.40E-05
Te-125m	7.74E+00
Te-127	5.88E+01
Te-127m	6.00E+01
Te-129	4.74E+01
Te-129m	7.38E+01
Te-131m	9.48E-09
Te-132	5.34E-04
Th-228	2.04E-07
Th-231	1.52E-03
Th-234	2.29E-05
Tl-208	7.08E-08
Tm-171	6.30E-07
U-232	1.31E-06
U-233	9.18E-08
U-234	6.93E-05
U-235	1.52E-03
U-236	2.68E-03
U-237	3.87E-03
U-238	2.29E-05
Xe-131m	2.03E-01
Xe-133	7.53E-03
Xe-133m	3.06E-06
Y-90	6.03E+02
Y-91	9.93E+03
YPu-236	1.14E-04
YPu-237	7.38E-05
YPu-238	8.28E-01
YPu-239	9.51E-02
YPu-240	3.66E-02
YPu-241	5.97E+00
YPu-242	1.36E-05
Zr-93	8.04E-03
Zr-95	1.19E+04

Table C-2 – L-Experimental Facility Radiological Material Inventory
The following table lists the maximum assumed inventory at the various locations associated with the LEF process in units of MURR assemblies of inventory.

LOCATION	PROCESS	QTY	REMARKS
Furnace Area (FA)			
Furnace Area (Trailer Space)	Melting Furnace/Filters/Offgas Ducting	5 MURR	Assumes 1 MURR molten in furnace crucible, and 4 ingots with used filters sets awaiting transportation from trailer space.
	Sample Analysis	15/1000 MURR per sample	Assume 1 samples awaiting transfer and storage. 0.015 MURR
Crane Aisle Control Room (CC)			
Crane Aisle Control Room	Shielded Crane Control Room	N/A	No radiological inventory
Furnace Control Station (FC)			
Furnace Control Station	External furnace control station	N/A	No radiological inventory
Receiving Area Transfer Bay (TB)			
Transfer Bay	Transfer from Disassembly Basin to Transfer Bay, transport vehicle to Purification Trailer Space.	1 MURR	Assumes 1 MURR SNF assembly per cask. 1 cask in transport vehicle.
Dry Cave (DC)			
Ingot Storage and Monitoring	Storage And Monitoring Of Initial Ingots for TSF	7 MURR	Assumes 6 ingots in storage, all treated MURR assemblies and 2 existing SNF assemblies (Assumed to be ½ MURR equivalents) in storage from another project.
Transportation (between Receiving Area and Furnace Area) (TR)			
Truck Transport	Transport of SNF MURR assemblies from Receiving Area to Furnace Area, or transport of treated SNF ingots from Furnace Area to Dry Cave via truck.	4 MURR	Assumes a maximum inventory of 4 MURR ingots per canister/cask. 1 canister/cask per transport.

Note: The LEF process will operate in a batch mode (load furnace, melt, solidify, unload). One ingot is assumed to be roughly equivalent to one MURR assembly.

APPENDIX D

HAZARD EVALUATION TABLES

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-1	E-1	Radiological release due to fire in the Furnace Area during truck loading/ unloading. Location: Furnace Area Hazard Source: SNF, ingots, and contamination in off-gas system and filters[1], deionizers, contaminated basin water in cask.	Truck fire. Ignition source: crane/ power tool electrical short; thermal or friction source from truck; Truck fuel, other combustibles in area.	Vehicle design Electrical equipment design codes	Transient Combustible Control Program, Trained personnel, SOPs (Vehicle entry/use controls)	U 1,8	EU 14	Building Design, HVAC system design, Ingot canister design	Fire Department, Transient Combustible Control Program, EOPs, Trained personnel. First Responders/ portable fire extinguishers	Onsite 1: High Onsite 2: High Offsite: Low Assumes 5 MURR and 8 deionizer vessels [0, 3] involved. Assumes fire spreads to the purification cells.	Onsite 1: Moderate Onsite 2: Moderate Offsite: Neg.	4 4 6	8 8 12
FA-2	E-1	Radiological release due to fire during furnace operation. Location: Furnace Area Hazard Source: Melted or unmelted SNF, ingots, contamination in off-gas system and filters	Fire. Ignition source: electrical short; friction, thermal ignition sources from crane or furnace (furnace power and clam shell heaters); Combustibles in area.	NFPA standards, Electrical equipment design codes, Crane design	Transient Combustible Control Program, Trained personnel, SOPs(Vehicle entry/use controls; Hazardous material control)	A 2,8	U 14	Building Design, HVAC system design, Ingot and canister design	Fire Department, Transient Combustible Control Program, EOPs, Trained personnel.	Onsite 1: High Onsite 2: High Offsite: Low Assumes 5 MURR involved. Assumes fire does not spread to the purification cells	Onsite 1: Low Onsite 2: Low Offsite: Neg.	1 1 3	6 6 12

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-2A	E-1	Radiological release due to full facility fire starting in LEF and propagating through 105-L. Location: Building 105-L Hazard Source: Melted or unmelted SNF, ingots, contamination in off-gas system and filters, moderator, process water deionizers, disassembly basin, dry cave area.	Fire. Ignition source: electrical short; friction, thermal ignition sources from crane or furnace (furnace power and clam shell heaters); Combustibles in area.	NFPA standards, Electrical equipment design codes, Crane design, Concrete walls separating areas.	Transient Combustible Control Program, Trained personnel, SOPs (Vehicle entry/use controls; Hazardous material control)	U 2,8,14	EU 2,8,14	Building Design, HVAC system design, Ingot and canister design	Fire Department, Transient Combustible Control Program, EOPs, Trained personnel.	Onsite 1: High Onsite 2: High Offsite: Low	Onsite 1: Moderate Onsite 2: Moderate Offsite: Neg.	4 4 6	8 8 12

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-3	E-2	Radiological material release due to an explosion during loading/ unloading. Location: Furnace Area Hazard Source: SNF, ingots, contamination in the off-gas system and filters, contaminated basin water in cask.	Explosion Ignition source: Trucks, crane, electrical circuits, unknown ignition source. Truck fuel, hydrogen evolved from truck battery and radiolysis of basin water in cask.	Battery design, cask design, NFPA standards, vehicle design	Trained personnel, SOPs, Transient Combustible Control Program	U 1	NA	Building design, Fire suppression equipment, Ingot canister design	Trained personnel, Fire Department, Transient Combustible Control Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1% of 5 MURR [3] involved in solid form. Assumes no or insignificant fire resulting from explosion.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
FA-4	E-2	Radiological release due to steam-related explosion or rapid steam generation in furnace. Location: Furnace Area Hazard Source: Melted SNF in furnace, contamination in off-gas filters/system.	Mixing of water and molten metal in or near furnace. Introduction via furnace cooling water; residual moisture on items introduced to the molten metal (e.g. SNF, sampling tube, or feed material), Natural phenomena	Furnace design (crucible), Offgas System design, Secondary Confinement (enclosure) design, Fuel basket design, Building design, Fire suppression system design, Moisture sensors in furnace for automatic shutdown [10].	Trained Personnel, SOPs (Vehicle entry/use and hazardous material control, Fuel basket check), furnace/cooling system preventive maintenance program, Slow furnace heatup procedures to dry charged SNF and feedstock, Basin water chemistry control	A 8	BEU 15	Offgas System design, Secondary confinement (enclosure) design, Ventilation design (stack release), Building design	EOPs, Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assume 1.5 MURR [0, 7] (crucible and offgas system) involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	1 1 3	11 11 11

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-5	E-2	Radiological release due to steam-related explosion or rapid steam generation in floor drain following a molten spill. Location: Furnace Area Hazard Source: Melted SNF in furnace, contamination in off-gas filters/system.	Breach or breakage of crucible, spilling molten SNF. Flow of molten material to process drain in floor adjacent to furnace (where secondary furnace cooling water is discharged)	Furnace design (Crucible; Crucible liner), Secondary Confinement (enclosure) design, Construction of floor drain (blocked), Cooling water discharge outside of furnace area, cofferdam, furnace drip pan design	Trained Personnel, SOPs (Vehicle entry/use and hazardous material control) . Basin water chemistry control	U 8	BEU 15	HVAC design, Building design	EOPs, Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assume 1.0 MURR (melt from crucible involved.)	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	4 4 6	11 11 11
FA-6	E-3	Radiological surface contamination release due to flooding. Location: Furnace Area Hazard Source: ingots, contamination in off-gas system filters	Flooding of trailer space due to clogging/back-up of process floor drain combined with continuing discharge of furnace secondary cooling water into the drain.	Process drain design (Drains are blocked), Secondary cooling water discharges outside of furnace area	Periodic drain inspection clearing/ preventive maintenance.	A 8	NA	Building design, Ingot or filter canister design, Furnace elevation above floor	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 4 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-7	E-3	Radiological release due to mishandling of SNF assemblies during furnace loading. Location: Furnace Area Hazard Source: SNF assembly; contamination in off-gas system or filters.	Worker error, SNF assembly and lifting tool dropped, pierced/damaged with remote manipulator; drops on/breaches off-gas system [5].	Crane control system design, Lifting tool design, Offgas system design, SNF assembly design, Furnace design	SOPs, Trained personnel, Hoisting and Rigging Program, Crane preventive maintenance	A 4	NA	Building Design, HVAC design,	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1.5 MURR [5, 6, 7] involved. (crucible and offgas system)	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA
FA-8	E-3	Radiological release from SNF and/or contaminated water in cask due to damage caused by crane/remote handling system failure during cask unloading and furnace loading Location: Furnace Area Hazard Source: SNF Assembly, contaminated water from cask, contamination in off-gas system or filters.	Crane material or control system failure. Runaway crane/remote manipulator, hoist, cable drum brake failure, cable failure, dropped load, mechanical, electrical control system failure.	Crane design, Crane control system design, SNF assembly design	SOPs, Trained personnel, Hoisting and Rigging Program, Crane preventive maintenance	U 5	NA	Building Design, HVAC design, Crane physical movement or rate limits	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1 % of 1.5 MURR [5, 6, 7] involved. (crucible and offgas system)	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-9	E-3	Radiological release due to mishandling of ingots during furnace unloading. Location: Furnace Area Hazard Source: Ingots; contamination in off-gas or SW filter.	Worker error. Ingot dropped, pierced/damaged with remote manipulator; drops on/breaches off-gas system[5].	Crane control system design, Offgas system design, Ingot material integrity, Furnace design	SOPs, Trained personnel, Hoisting and Rigging Program, Crane preventive maintenance	A 4	NA	Building Design, HVAC design, Physical form of ingots	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1 % of 1.5 MURR [5,6,7] involved. (crucible and offgas system)	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA
FA-10	E-3	Radiological release from ingots due to damage caused by crane/remote handling system failure during furnace unloading Location: Furnace Area Hazard Source: Ingots, contamination in off-gas system or filters.	Crane material or control system failure. Runaway crane/remote manipulator, hoist, cable drum brake failure, cable failure, dropped load, mechanical, electrical control system failure.	Crane design, Crane control system design, Ingot material integrity	SOPs, Trained personnel, Hoisting and Rigging Program, Crane preventive maintenance	U 5	NA	Building Design, HVAC design, physical form of ingots, Crane physical movement or rate limits	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1% of 1.5 MURR [5,6,7] involved. (crucible and offgas system)	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-11	E-3	Radiological release due to furnace upset resulting from objects falling from overhead during melting operation. Location: Furnace Area Hazard Source: Molten SNF; contamination in off-gas system/ filters.	Aging structures in overhead (e.g. crane components, light fixtures, degraded ceiling concrete) fall and breach furnace, off-gas system resulting in upset crucible/molten spill and release of filter particulate.	Building design, Seismic qualification, Concrete strength, Crane Design, Equipment mounting design, Secondary confinement (enclosure) design, Offgas system design	SOPs (crane position), Trained personnel, Preventive Maintenance Program	U 5, 6	EU 15	Building design, HVAC design, Offgas system design, Secondary confinement design	Trained personnel	Onsite 1: Moderate Onsite 2: Moderate Offsite: Negligible Assume 1.0 MURR in molten material in furnace involved and 0.5 MURR worth of particulate in offgas system. [7]	Onsite 1: Low Onsite 2: Neg Offsite: Neg	5 5 12	9 12 12
FA-12	E-3	Radiological release from SNF due to mishandling of molten metal during ingot sampling. Location: Furnace Area Hazard Source: Molten or solidified SNF sample.	Worker error, breach of sample device, remote handling system failure, inadequate procedure.	Remote manipulator design, Crane control system design, Offgas/ sampling system design, Furnace design	SOPs, Trained personnel, Remote manipulator preventive maintenance	A 4,5,8	NA	Building Design, HEPA filter system design, Solidified sample physical form	Trained personnel, Restricting sample transfer until solidified	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 0.015 MURR [8] involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-13	E-3	Radiological release of off-gas contamination due to mishandling of zeolite or HEPA filter during change out/ disposal. Location: Furnace Area Hazard Source: Contamination in off-gas system and filters.	Worker error, zeolite or HEPA filter dropped pierced/damaged with remote manipulator.	Building design, Crane/remote manipulator design, crane control system design,, filter containment design	SOPs (remote handling operations); Trained personnel, Remote manipulator preventive maintenance, Hoisting and Rigging Program,	A 4	U 7	Radiation monitors / alarms, HVAC design, filter containment design	Trained personnel; SOPS (Controlled access to furnace area); Radiation Protection Program	Onsite 1: Moderate Onsite 2: Low Offsite: Negligible Assume 0.5 MURR [6, 7] involved.	Onsite 1: Low Onsite 2: Neg Offsite: Neg	2 3 12	6 12 12
FA-14	E-3	Radiological release of off-gas contamination caused by crane/remote handling system failure during zeolite/ HEPA filter changeout or filter disposal. Location: Furnace Area Hazard Source: Contamination in off-gas system and filters	Runaway crane/remote manipulator, hoist, cable drum brake failure; cable failure; mechanical, electrical or control system failure; dropped load; breach of filters	Equipment design Crane/remote manipulator design, Crane control system design,, Filter containment design	SOPs (remote handling operations); Trained personnel, Remote manipulator preventive maintenance, Hoisting and Rigging Program, operational hoist height restrictions	U 5	U 5	Building design; HVAC design, filter containment design Radiation monitors / alarms	SOPs; Trained personnel; Radiation Protection Program	Onsite 1: Moderate Onsite 2: Low Offsite: Negligible Assume 0.5 MURR [6, 7] involved.	Onsite 1: Low Onsite 2: Neg Offsite: Neg	5 6 12	6 12 12

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-15	E-3	Radiological release due to failure of crucible during melting operations. Location: Furnace Area Hazard Source: Molten SNF.	Breach or breakage of crucible, spilling molten SNF on the floor.	Crucible design, Crucible liner, Furnace design, Furnace drip pan design, Furnace secondary confinement (enclosure) design	SOPs (Crucible liner use); Trained personnel, Crucible liner, Remote visual inspection, Crucible/ furnace heat-up /cool-down rate limits	A 8	EU 15	Building design; Building HVAC design, Furnace Secondary confinement (enclosure), Secondary confinement (HEPA filters), Offgas system Radiation monitors / alarms	Trained personnel; Radiation Protection Program	Onsite 1: Moderate Onsite 2: Low Offsite: Negligible Assume 1 molten MURR [0] involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	2 3 12	12 12 12
FA-16	E-3	Radiological release due to loss of ingot, confinement. Location: Furnace Area Hazard Source: Ingots	Material fracture, chipping, spalling of ingot; poor material integrity upon solidification.	Crucible design, Ingot physical form/integrity	SOPs; Trained personnel, Furnace cooling rate limits, ingot removal procedures from crucible	A 8	NA	Building design; Building HVAC design; Radiation monitors / alarms, Ingot canister design	Trained personnel; Radiation Protection Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1% of 1 MURR [0] involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-17	E-3	Radiological release due to over-temperature excursion in furnace with excessive off-gas release, zeolite bed and HEPA filter burn-up/damage with release of loaded content. Location: Furnace Area Hazard Source: Molten SNF, contamination in off-gas	Equipment failure; operator error; loss of cooling for furnace resulting in over-temperature condition.	Equipment design; Cooling system design, Temperature probe design, Furnace automatic shutdown features	SOPs (sensor functionality checks/temperature monitoring); Trained personnel; Preventive maintenance, LCOs	A 4,5,8	BEU 15	Building design; Building ventilation design (stack release); Radiation monitors / alarms, Offgas system and filter design, Secondary confinement (enclosure) design	Trained personnel; Emergency Preparedness Program; Radiation Protection Program, Filter monitoring with designated limits for removal.	Onsite 1: High Onsite 2: High Offsite: Low Assume 1.5 MURR [6,7,9] involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	1 1 3	11 11 11
FA-18	E-3	Radiological release due to furnace cooling water failure during melting operation resulting in extreme overtemperature excursion Location: Furnace Area Hazard Source: Molten SNF, ingots, contamination in off-gas system.	Operator error; power failure; blockage or breach of furnace cooling water lines external to building due to freezing temperatures.	Freeze protection; Equipment design, Redundant temperature sensors, Automatic shutdown feature on loss of cooling water flow, Crucible and crucible liner.	SOPs (temperature sensor loop checks); Trained personnel, preventive maintenance of closed loop cooling system mixture.	A 4,5	BEU 15	Building design; Building ventilation design (stack release); Radiation monitors / alarms, Offgas system and filter design, Secondary confinement (enclosure) design	EOPs; Trained personnel; Radiation Protection Program, Filter monitoring with designated limits for removal.	Onsite 1: High Onsite 2: High Offsite: Low Assume 1.5 MURR [0,7] involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	1 1 3	11 11 11

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-19	E-3	Radiological release due to lack/loss of off-gas exhaust treatment. Location: Furnace Area Hazard Source: Molten SNF off-gas	Off-gas release from molten SNF above 500 °C. Ineffective zeolite-cesium reaction. Worker error; equipment failure. HEPA filter degradation.	Offgas system and filter media design	SOPs; Trained personnel; Offgas system ,preventive maintenance / filter replacement, HVAC operating limits	A 4,5,8	NA	Building design; Building HVAC design; Radiation monitors / alarms, CAMS, Secondary confinement (enclosure) design	Trained personnel; Radiation Protection Program, Filter monitoring with designated limits for removal.	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1.5 MURR [6, 7, 9] involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA
FA-20	E-3	Radiological release due to leak in off-gas system confinement during normal operating conditions. Location: Furnace Area Hazard Source: Molten SNF off-gas, contamination in off-gas system.	Improper installation, material failure, inadequate procedures, worker error.	Offgas system and filter design, Remote manipulator design	SOPs; Trained personnel; Preventive maintenance	A 4,5,8	NA	Secondary Confinement (enclosure), HVAC design and operating limits, Building design; Radiation monitors / alarms, CAMS	Trained personnel; Radiation Protection Program, Filter Monitoring	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1% of 1.5 MURR [6, 7, 9] involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA
FA-21	E-3	Radiological release due to off-gas/exhaust system failure. Location: Furnace Area Hazard Source: Molten SNF off-gas	Loss of building exhaust fans, off-gas system fans, loss of electric power, ducting breach.	Electrical system design; Equipment design / redundancy	SOPs; Trained personnel; Preventive maintenance	A 5	NA	Building design; Building HVAC design; Back-up electrical power systems, Radiation monitors / alarms	Trained personnel; Radiation Protection Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1.5 MURR [6, 7, 9] involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-22	E-4	Direct radiological exposure of workers to SNF radiation. Location: Furnace Area Hazard Source: SNF Assembly	Worker error; lack or loss of shielding.	Viewing window shielding design, Building design	Trained personnel, Preventive maintenance; SOPs (Remote operations), Radiation Protection Program	A 7	U 7	Shielding design; Radiation monitors / alarms	Trained personnel; Radiation Protection Program	Onsite 1: High Onsite 2: Low Offsite: Negligible Assume 1 MURR Assume>2000R/hr @1 ft	Onsite 1: Low Onsite 2: Neg Offsite: Neg Assume 1 MURR Assume 35 mR/hr in remote viewing area	1 3 12	6 12 12
FA-23	E-4	Direct radiological exposure of workers from ingot. Location: Furnace Area Hazard Source: Ingots	Worker error; lack or loss of shielding	Viewing window shielding design	Trained personnel, Preventive maintenance; SOPs (Remote operations); Radiation Protection Program	A 7	U 7	Shielding design; Cask design	Trained personnel; Radiation Protection Program	Onsite 1: High Onsite 2: Low Offsite: Negligible Assume 1 or more MURR ingots involved. Assume>2000R/hr/ MURR @ 1ft.	Onsite 1: Low Onsite 2: Neg Offsite: Neg	1 3 12	6 12 12
FA-24	E-4	Direct radiological exposure of workers during filter change out or disposal. Location: Furnace Area Hazard Source: Contamination in off-gas system, loaded filters	Worker error; lack or loss of shielding.	Viewing window shielding design	Trained Personnel, Preventive maintenance; SOPs (Remote operations); Radiation Protection Program	A 7	U 7	Shielding design; Cask design	Trained personnel; Radiation Protection Program	Onsite 1: High Onsite 2: Low Offsite: Negligible Assume 1 filter involved (0.5 MURR) Assume>2000R/hr/ filter on contact	Onsite 1: Low Onsite 2: Neg Offsite: Neg	1 3 12	6 12 12

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-25	E-5	Criticality due to unfavorable configuration of stratified ingots due to lack of homogenous Al-U mixture during or after melting operations. Location: Furnace Area Hazard Source: Stratified U-235 in solidified ingots	Worker error or equipment failure leading to inadequate stirring of molten SNF during furnace operation resulting in localized formation of enriched U_{235} sphere within the ingot. Assumed close proximity storage of two or more [10] such ingots results in unfavorable configuration and criticality.	Equipment design, Crucible design/geometry	Criticality Control Program; SOPs (Furnace melt cycle); Trained personnel	U 3	BEU 17	Building design; Ingot canister design	ERPs; Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assumes 2 stratified MURR ingots involved	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	4 4 6	11 11 11
FA-26	E-5	Criticality due to undetected formation and collection of concentrated U mixture in crucible bottom from two or more melt batches Location: Furnace Area Hazard Source: U-235 from SNF in reused crucible	Formation and settling of enriched U_{235} within crucible. Incomplete removal and accumulation of U-235 in bottom of reused crucible. Results in unfavorable configuration and criticality within reused crucible.	Crucible design, Remote visual inspection equipment.	Criticality Control Program; SOPs (liner changed for each melt); Trained personnel, Crucible inspection	U 3	BEU 17	Building design; Offgas system design, Secondary confinement (enclosure) design	ERPs; Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assume 1 MURR batch involved with accumulated U-235 from previous melts.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	4 4 6	11 11 11

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-27	E-6	Radiological release due to external fire impacting facility. Location: Furnace Area Hazard Source: Melted or unmelted SNF; ingots; contamination in off-gas system and filters, and deionizers	External fire; forest/brush fire; external vehicle fire	Building design; Vehicle design	Grounds keeping; SOPs (cease operations upon fire notification); Preventive maintenance (vehicle); Trained personnel	A 9	EU 1,8	Building design; Building HVAC system; Fire suppression system, Ingot canister design	EOPs; Trained personnel; Transient Combustible Control Program, Fire Department / Forest Service	Onsite 1: High Onsite 2: High Offsite: Low Assumes 5 MURR and 8 deionizer vessels ^{0,3} involved. Assumes fire spreads to the purification cells.	Onsite 1: Moderate Onsite 2: Moderate Offsite: Neg	1 1 3	8 8 12
FA-28	E-6	Damage to SNF, ingot, off-gas system, filters from external explosion during resulting in radiological release. Location: Furnace Area Hazard Source: SNF; ingots; contamination in off-gas system, and filters	External explosion /deflagration (e.g. vehicle fuel tank, tanker truck, high pressure gas storage cylinders).	Building design; Vehicle design; Gas bottle design	Preventive maintenance (Vehicle entry/use and hazardous material control); SOPs; Trained personnel, Flammable Material Limits	U 9	EU 1,8	Building design; Building HVAC system, Fire suppression system, Ingot canister design	Trained personnel, Transient Combustible Control Program	Onsite 1: Moderate Onsite 2: Low Offsite: Negligible Assume 5 MURR involved: (1 molten, and 1% of 4 solid ingots)	Onsite 1: Low Onsite 2: Low Offsite: Neg	5 6 12	9 9 12

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-29	E-6	Damage from external surface vehicle impact resulting in radiological release. Location: Furnace Area Hazard Source: SNF; ingots; contamination in off-gas system, filters.	Surface vehicle impact. Worker error or equipment failure.	Building Design, Vehicle design; Minimal local traffic	SOPs (speed limits and traffic control); Trained personnel, Vehicle preventive maintenance, Site speed limits	U 12	EU 12	Building design; Building HVAC system, Ingot canister design	ERPs; Trained personnel	Onsite 1: Moderate Onsite 2: Low Offsite: Negligible Assume 5 MURR involved (1 molten, and 1% of 4 solid ingots	Onsite 1: Moderate Onsite 2: Low Offsite: Neg	5 6 12	8 9 12
FA-30	E-6	Damage due to external crane mishap resulting in radiological release. Location: Furnace Area Hazard Source: SNF; ingots; filters.	External crane drop mishap, load impact strikes area.	Building Design, Crane design	SOPs; Trained personnel, Hoist and Rigging Program	U 7	NA	Building design; Building HVAC system, Ingot canister design	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 5 MURR involved.(solid form)	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-31	E-6	Damage from aircraft impact resulting in release of radiological material. Location: Furnace Area Hazard Source: Melted or unmelted SNF, ingots, contamination in off-gas system and filters.	Helicopter impact	Building Design (target area profile), Aircraft Design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	EU 13	BEU 8, 13	Building design, Ingot canister design, Fire Suppression Systems	Trained personnel, Fire Department	Onsite 1: High Onsite 2: High Offsite: Low Assume 5 MURR involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	7 7 9	11 11 11
FA-32	E-6	Damage from aircraft impact resulting in release of radiological material. Location: Furnace Area Hazard Source: Melted or unmelted SNF, ingots, contamination in off-gas system and filters, deionizers	Airplane impact	Building Design (target area profile), Aircraft Design	Trained Pilots, SRS flight restrictions, Aircraft preventive maintenance	BEU 10	NA	Building design, Ingot canister design, Fire Suppression Systems	Trained personnel, Fire Department	Onsite 1: High Onsite 2: High Offsite: Low Assume 5 MURR and 4 deionizers involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	10 10 10	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-33	E-7	Release of radiological material due to damage from earthquake event. Location: Furnace Area Hazard Source: Melted or unmelted SNF; ingots; contamination in off-gas system and filters, deionizers.	Earthquake (PC-2), loss of structural crane support, falling debris, crucible and/or confinement failure.	Building seismic design, Crane design, Furnace secondary confinement (enclosure), Offgas system design	SOP (crane position)	U 10,11	BEU 19	Building design, HVAC system design, Ingot canister design	EOPs; Trained personnel	Onsite 1: Moderate Onsite 2: Low Offsite: Negligible Assumes 1 molten MURR, 1 % of 4 solid MURR ingots and 8 deionizers are involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	5 6 12	11 11 11
FA-34	E-7	Radiological material release due to earthquake followed by fire. Location: Trailer Space Hazard Source: Molten SNF, ingots, contamination in off-gas system and filters, and deionizers.	Earthquake (PC-2), fire	Building seismic design	Transient Combustible Control Program	U 10,11	EU 14, 20	Building design; Fire suppression system; Ingot canister design	EOPs; Trained personnel; Transient combustible control program, Fire Department	Onsite 1: High Onsite 2: High Offsite: Low Assume 5 MURR and 8 deionizers consumed in fire.	Onsite 1: Moderate Onsite 2: Neg Offsite: Neg	4 4 6	8 12 12

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-35	.E-7	Release of radiological material due to tornado event. Location: Furnace Area Hazard Source: Molten SNF; ingots; contamination in off-gas system and filters, and deionizers	Tornado (PC-2) (BDBE -Tornado analysis not required for a PC-2 structure)	Building design; Secondary confinement (enclosure) design	None	EU 10,11	BEU 8, 19	Building design, Ingot canister design,	EOPs; Trained personnel	Onsite 1: High Onsite 2: Moderate Offsite: Negligible Assumes 1 molten MURR, 1% of 4 solid MURR ingots and 8 deionizers are involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	7 8 12	11 11 11
FA-36	E-7	Release of radiological material due to SNF, ingot, off-gas system and filter, and deionizer damage due to high straight wind event. Location: Furnace Area Hazard Source: Melted or unmelted SNF; ingots; contamination in off-gas system and filters, and deionizers	High velocity straight winds. (PC-2)	Building design; Secondary confinement (enclosure) design	None	A 11	BEU 8, 19	Building design, Ingot canister design	EOPs; Trained personnel	Onsite 1: High Onsite 2: Moderate Offsite: Negligible Assumes 1 molten MURR, 15 of 4 solid MURR ingots and 8 deionizers involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	1 2 12	11 11 11

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FA-37	E-7	Release of radiological material due to damage from lightning strike. Location: Furnace Area Hazard Source: Ingots; contamination in off-gas system	Direct lightning strike.	Building design; Lightning protection, Furnace secondary confinement (enclosure)	Transient Combustible Control Program	EU 10	EU 10	Building design, Ingot canister design, Furnace secondary confinement (enclosure)	Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assume 4 MURR ingots involved.	Onsite 1: Moderate Onsite 2: Moderate Offsite: Neg	7 7 9	8 8 12
FA-38	E-7	Radiological surface contamination release due to flooding. Location: Furnace Area Hazard Source: ingots, contamination in off-gas system filters	Flooding of trailer space due to heavy rain	Building design; Site grading; Building location / elevation	Process Drain, Storm Drain periodic inspection/ maintenance	U 11	NA	Building design, Ingot canister design, Furnace elevation above floor	Trained personnel, Environmental/ground water remediation	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 4 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
FA-39	E-6	Radiological release due to off-gas/exhaust system failure. Location: Furnace Area Hazard Source: Molten SNF off-gas	Complete loss of offsite power to LEF due to 115 kv system failure, vehicle crash, and NPH events	115 KV system design	SOPs; Trained personnel	A 14	NA	Building design; Building HVAC design; UPS, Radiation monitors / alarms	Trained personnel; EOPs; Radiation Protection Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1.5 MURR [6, 7, 9] involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-1, Hazard Evaluation Table for L-Experimental Facility Furnace Area, Unmitigated/Mitigated Consequences (continued)

Superscript Notes:

[0]-Assumes 1 MURR per melt batch.
[1]–Offgas system "filters" includes used zeolite and HEPA filters.
[2]–Note Deleted.
[3]–Assumes maximum SNF (including melted or unmelted SNF, ingots, contamination in off-gas system and filters) in FA at any one time = 5 MURR.
[4]-Assumes simultaneous furnace heating and cooling system failure or shutdown.
[5]-Worst case: Load drops on/breaches off-gas system.
[6]–Assumes off-gas filters replaced after 5th batch.
[7]-Radioactive material in off-gas system is assumed to be 10% of each MURR batch. Maximum expected inventory in offgas system = 10% x 5 MURR batches = 0.5 MURR.
[8]-Assume sample size = 1.5 % of a MURR.
[9]– Assumes 1 MURR in crucible and 0.5 MURR worth of contamination in the off-gas system.
[10]_Moisture detectors are not credited for NPH events.

Notes / References for Frequency Levels:

1. Initiator frequency for truck fire/explosion based on S-CLC-K-00147 and engineering judgement.
2. Initiator frequency for significant fire derived from WSRC-TR-94-0188, calculated applicable area and engineering judgement.
3. Explosion from rupture of compressed gas systems derived from WSRC-TR-93-262.
4. Mishandling accident (human error) frequency derived from WSRC-93-581 p. 78 for failure probability and SFS-RSE-98-0150 for material movement/operations frequency.
5. Electrical, mechanical or control system failure frequency derived from WSRC-TR-93-262 selected electrical and I&C component failure rates averaged and engineering judgement.
6. Frequency derived as anticipated based on actual concrete ceiling degradation from C-Reactor operational history.
7. Derived from WSRC-TR-93-581 and engineering judgement.
8. Engineering judgement/discussions with facility and material experts.
9. Derived from WSRC-TR-94-0188 and engineering judgement.
10. Derived from WSRC-RP-95-915, Rev 0 and engineering judgement.
11. Frequency derived from WSRC-TM-95-1.
12. Frequency derived from WSRC-TR-93-581 Table 4 Item 22, restricted maneuvering area (i.e. congested road).
13. WSRC-RP-95-915 and the area square footage yield a helicopter impact frequency of "EU."
14. Frequency derived from WSRC-TR-99-00047 and engineering judgement.
15. Frequency is from S-CLC-L-00018.
16. WSRC-TR-93-581, page 78, #27 assuming 20 operations per year and engineering judgement.
17. N-NCS-L-00010 and engineering judgement.
18. WSRC Engineering Standard 1060 and engineering judgement.
19. WSRC-TR-95-0054, Rev. 2 and engineering judgement.
20. Seismic induced fire frequency for PWDIs from S-CLC-K-00128.

Table D-2, Hazard Evaluation Table for L-Experimental Facility Crane Aisle Control Room, Unmitigated/Mitigated Consequences

Event No.	Event Cate-gory	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				design	Administration	Unmitigated	Mitigated	design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
CC-1	E-1	Localized fire. Equipment damage. Personnel injury Location: Crane Aisle Control Room, corridors, stairs, etc. Hazard Source: Toxic fuming combustibles.	Electrical short; thermal or friction ignition sources; combustibles in the CC Room. Ignition source: Heaters, electrical circuits.	Electrical equipment design codes; NFPA Standards	Transient Combustible Control Program; Trained personnel; SOPs	A 1	NA	Building design, Portable fire extinguisher	Trained personnel; Transient Combustible Control Program, Fire Department	Standard industrial hazard.	N/A	N/A	N/A
CC-2	E-2	Localized explosion. Equipment damage. Location: Crane Aisle Control Room Hazard Source: Pressure wave	Compressed gas CO_2 bottle, steam headers/ lines	Gas bottle design; Steam header design	Trained personnel, Preventive maintenance, Pressure limits	A 2	NA	Building design; Building HVAC system	Trained personnel	Standard Industrial hazard.	N/A	N/A	N/A

Table D-2, Hazard Evaluation Table for L-Experimental Facility Crane Aisle Control Room, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				design	Administration	Unmitigated	Mitigated	design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
CC-3	E-4	Direct exposure to radiological material in Furnace Area due to lack/loss of shielding. Location: Personnel in Crane Aisle Control Room. Radiological material located in Furnace Area. Hazard Source: Emitted radiation from SNF, ingots, offgas system/filters.	Lack or loss of shielding in viewing window(s); leakage of zinc-bromide solution from window with no makeup.	Remote operations; Shielding design	Preventive maintenance; SOPs (Occupation of Control Room controlled – Radiation Area); Radiation Protection Program	A 6	U 7	Shielding design (zinc bromide filled window); Radiation monitors / alarms	Trained personnel; Radiation Protection Program	Onsite 1: Moderate Onsite 2: Negligible Offsite: Negligible Assumes a total loss of window shielding water could go unnoticed by personnel entering the Crane Aisle Control Room for several hours of crane operation.	Onsite 1: Low Onsite 2: Neg Offsite: Neg	2 12 12	6 12 12

Table D-2, Hazard Evaluation Table for L-Experimental Facility Crane Aisle Control Room, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				design	Administration	Unmitigated	Mitigated	design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
CC-4	E-4	Direct exposure to radiological material in Furnace Area due to shielded window breakage. Location: Personnel in Crane Aisle Control Room. Radiological material located in Furnace Area. Hazard Source: Emitted radiation from SNF, ingots, offgas system/filters.	Shielded window glass breakage due to seismic event or crane hook overswing impacting window.	Remote operations. Crane control system design, Crane trolley lateral stops, Window / pane design	Preventive maintenance; SOPs; Radiation Protection Program Crane control restrictions, Trained personnel.	U 6	NA	Window /pane design; Radiation monitors / alarms	Trained personnel; Radiation Protection Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Consequence level assumes personnel evacuate the Crane Aisle Control Room shortly after the event occurs.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
CC-5	E-6	External fire. Equipment damage. Location: Crane Aisle Control Room Hazard Source: Electrical energy, toxic fuming combustibles.	External fire; forest /brush fire; vehicle fire	Building design, Vehicle design	Groundskeeping; SOPs; Preventive maintenance (vehicle); Trained personnel	A 1	NA	Building design; Building HVAC system; Portable fire extinguisher	Trained personnel; Transient Combustible Control Program, Fire Department / Forest Service	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-2, Hazard Evaluation Table for L-Experimental Facility Crane Aisle Control Room, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				design	Administration	Unmitigated	Mitigated	design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
CC-6	E-6	External explosion. Equipment damage. Location: Crane Aisle Control Room Hazard Source: pressure wave	External explosion /deflagration (e.g. vehicle fuel tank, tanker truck, UPS batteries) in the Furnace Area	Building design, vehicle design	Preventive maintenance (vehicle), SOPs, Trained personnel	U 2	NA	Building design; Building HVAC system,	Trained personnel, Transient Combustible Control Program	Standard Industrial Hazards.	N/A	N/A	N/A
CC-7	E-6	Aircraft impact event. Equipment damage. Location: Crane Aisle Control Room Hazard Source: Electrical energy; toxic fuming combustibles; CO_2 bottles; steam lines	Helicopter impact.	Building Design, Aircraft Design	Trained Pilots, SRS flight restrictions	EU 4	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-2, Hazard Evaluation Table for L-Experimental Facility Crane Aisle Control Room, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				design	Administration	Unmitigated	Mitigated	design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
CC-8	E-6	Aircraft impact event. Equipment damage. Personnel injury. Location: Crane Aisle Control Room Hazard Source: Electrical energy; toxic fuming combustibles; CO_2 bottles; steam lines	Airplane impact.	Building Design, Aircraft Design	Trained Pilots, SRS flight restrictions	BEU 3	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
CC-9	E-7	NPH earthquake event. Equipment damage. Location: Crane Aisle Control Room Hazard Source: Falling debris, Electrical energy; Steam lines	Earthquake (PC-2), loss of structural support, falling debris.	Building design	None	U 3,5	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-2, Hazard Evaluation Table for L-Experimental Facility Crane Aisle Control Room, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				design	Administration	Unmitigated	Mitigated	design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
CC-10	E-7	Tornado event. Equipment damage. Location: Crane Aisle Control Room Hazard Source: Structural damage; electrical energy; missile hazards to personnel; steam/ compressed gas explosion	Tornado (PC-2)	Building design	None	EU 3,5	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
CC-11	E-7	High wind event. Location: Crane Aisle Control Room Hazard Source: Electrical energy; missile hazards to personnel.	High velocity straight winds (PC-2).	Building design	None	A 3,5	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
CC-12	E-7	Lightning strike event. Equipment damage. Location: Crane Aisle Control Room Hazard Source: High energy	Direct lightning strike to facility.	Building design; Lightning protection	None	U 3	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-2, Hazard Evaluation Table for L-Experimental Facility Crane Aisle Control Room, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				design	Administration	Unmitigated	Mitigated	design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
CC-13	E-7	Earthquake event followed by fire. Location: Crane Aisle Control Room Hazard Source: Falling Debris, Electrical energy; toxic fuming combustibles; steam lines	Earthquake (PC-2); fire	Building design	Transient combustible control program	U 3,5	NA	Building design; Fire detection and suppression system;	Trained personnel; Transient combustible control program, Fire Department	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Notes / References for Frequency Levels:

1. Initiator frequency for fire derived from WSRC-TR-94-0188 and engineering judgement.
2. Explosion from rupture of compressed gas systems derived from WSRC-TR-93-262.
3. Derived from WSRC-RP-95-915, Rev 0 and engineering judgement.
4. WSRC-RP-95-915 and the area square footage yield a helicopter impact frequency of "EU."
5. Frequency derived from WSRC-TM-95-1.
6. Engineering judgement/discussions with facility and material experts.
7. WSRC-TR-93-581, page 76, #1 assuming 20 operations per year and engineering judgement.
8.

Table D-3, Hazard Evaluation Table for L-Experimental Facility - Furnace Control Station, Unmitigated/Mitigated Consequences

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FC-1	E-1	Localized fire. Equipment damage. Location: Furnace Control Station Hazard Source: Electrical energy, toxic fuming combustibles.	Electrical short; thermal or friction ignition sources; combustibles in FC Station.	Electrical equipment design codes; NFPA Standards,	Transient Combustible Control Program; Trained personnel; SOPs	A 1	NA	Portable fire extinguisher, Building design	Trained personnel; Transient Combustible Control Program	Standard industrial hazard.	N/A	N/A	N/A
FC-2	E-2	Localized explosion. Equipment damage. Location: Furnace Control Station Hazard Source: Pressure wave; electrical energy	Compressed gas cylinder rupture, CO_2.	Gas bottle design; mounting design	Trained personnel, Preventive maintenance, Pressure limits	EU 2	NA	None.	Trained personnel	Standard Industrial hazard.	N/A	N/A	N/A
FC-3	E-6	External fire. Equipment damage. Location: Furnace Control Station Hazard Source: Electrical energy; toxic fuming combustibles.	External fire; forest /brush fire; vehicle fire. Unknown ignition sources.	Building design, Vehicle design	Groundskeeping; Preventive maintenance (vehicle); Trained personnel	A 1,2	NA	Building design	Trained personnel; Transient Combustible Control Program, Fire Department / Forest Service	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-3, Hazard Evaluation Table for L-Experimental Facility - Furnace Control Station, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FC-4	E-6	External explosion. Equipment damage. Location: Furnace Control Station Hazard Source: Electrical energy; pressure wave; compressed gas	External explosion /deflagration (e.g. vehicle fuel tank, tanker truck, high pressure gas storage cylinders)	Vehicle design, Gas bottle design	Preventive maintenance (vehicle), Trained personnel	U 2	NA	Building design	Trained personnel	Standard Industrial Hazard.	N/A	N/A	N/A
FC-5	E-6	Surface vehicle impact event. Equipment damage. Location: Furnace Control Station Hazard Source: Impact energy, Electrical energy; compressed gas bottles	Surface vehicle impact.	Vehicle Design	Posted Vehicle Warning signs, Limits on Access and Speed near facility, Vehicle preventive maintenance	A 1,3	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-3, Hazard Evaluation Table for L-Experimental Facility - Furnace Control Station, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FC-6	E-6	Aircraft impact event. Equipment damage. Location: Furnace Control Station Hazard Source: Electrical energy; toxic fuming combustibles; compressed gas	Helicopter impact.	Aircraft design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	EU 5	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
FC-7	E-6	Aircraft impact event. Equipment damage. Location: Furnace Control Station Hazard Source: Electrical energy; toxic fuming combustibles; compressed gas	Airplane impact.	Building design	Trained pilots, SRS flight restrictions, Preventive maintenance (aircraft)	BEU 4	NA	Building design	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-3, Hazard Evaluation Table for L-Experimental Facility - Furnace Control Station, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FC-8	E-7	Earthquake event. Equipment damage. Location: Furnace Control Station Hazard Source: Structural failure; electrical energy.	Earthquake	None.	None.	U 4,6	NA	None.	Trained personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
FC-9	E-7	Tornado event. Equipment damage. Location: Furnace Control Station Hazard Source: Structural failure; electrical energy; missile hazards to personnel.	Tornado. Loss or damage to control station	None.	None.	EU 4,6	NA	Building Tie Downs.	Trained personnel, Designated shelters, Site Weather Warning System accuracy	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-3, Hazard Evaluation Table for L-Experimental Facility - Furnace Control Station, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FC-10	E-7	High wind event. Location: Furnace Control Station Hazard Source: Electrical energy; missile hazards to personnel.	High velocity straight winds. Loss or damage to control station	None.	None	A 6	NA	Building Tie Downs	Trained personnel, Designated shelters, Site Weather Warning System accuracy	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
FC-11	E-7	Lightning strike event. Equipment damage. Location: Furnace Control Station Hazard Source: High energy	Direct lightning strike to facility.	None	None	U 4	NA	None.	Trained personnel, Designated shelters, Site Weather Warning System accuracy	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
FC-12	E-7	Earthquake event followed by fire. Location: Furnace Control Station Hazard Source: Structural failure; electrical energy; toxic fuming combustibles	Earthquake, fire	None.	Transient Combustible control program, Trained Personnel, SOP's	U 4,6	NA	Building design; Fire suppression system	Trained personnel; Transient Combustible control program, Fire Department	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A

Table D-3, Hazard Evaluation Table for L-Experimental Facility - Furnace Control Station, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
FC-13	E-7	NPH flooding event. Equipment damage. Location; Furnace Control Station Hazard Source: Electrical energy	Flooding of Furnace Control Station due to heavy rain.	Site grading / Storm drainage design,	Storm drainage system preventive maintenance	U 6	NA	Facility Sumps/ Drainage	Trained Personnel	No radiological or chemical hazards associated with this station.	N/A	N/A	N/A
FC-14	E-7	Building collapse. Control Circuit and UPS Circuit damage. Location: Furnace Control Station Hazard Source: Structural Failure	NPH Event	None	None	U 4,6	NA	Building Design (PC-2)	Trained Personnel; EOPs	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assume 1.5 MURR [6, 7, 9] involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-3, Hazard Evaluation Table for L-Experimental Facility - Furnace Control Station, Unmitigated/Mitigated Consequences (continued)

Superscript Notes:

[1] – Assume simultaneous furnace heating and cooling system failure/shutdown.

Notes / References for Frequency Levels:

1. Initiator frequency for significant fire derived from WSRC-TR-94-0188, calculated applicable area and engineering judgement.
2. Explosion from rupture of compressed gas systems derived from WSRC-TR-93-262.
3. Frequency derived from WSRC-TR-93-581, Table 4 Item 22, Congested road.
4. Derived from WSRC-RP-95-915, Rev 0 and engineering judgement.
5. WSRC-RP-95-915 and the area square footage yield a helicopter impact frequency of "EU."
6. Frequency derived from WSRC-TM-95-1.

Table D-4, Hazard Evaluation Table for L-Experimental Facility Receiving Area Transfer Bay, Unmitigated/Mitigated Consequences

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TB-1	E-1	Radiological release due to a fire. Location: Transfer Bay Hazard Source: SNF assembly	Truck/crane/power tool electrical short, friction or thermal ignition source, truck fuel, combustibles in transfer bay	Vehicle design Electrical equipment design codes	Trained personnel (fire detected by local personnel); SOPs; Fire Department; Preventive maintenance (vehicle), Transient Combustible Control Program	A 1	U 9	Cask/canister design, Building design, Fire barriers, Fire resistant construction	Fire Department, Transient Combustible Control Program, EOPs, Trained personnel, First Responders/ portable fire extinguishers	Onsite 1: High Onsite 2: High Offsite: Negligible Assumes 1 MURR involved.	Onsite 1: Low Onsite 2: Neg Offsite: Neg	1 1 12	6 12 12
TB-2	E-2	Radiological release due to an explosion. Location: Transfer Bay Hazard Source: SNF assembly	Truck fuel, hydrogen evolved in truck or forklift battery. Ignition source: truck, crane, forklift, electrical circuits, other.	Battery design; Vehicle design, NFPA standards, Electrical equipment design codes, Crane design	Preventive maintenance (vehicle), Flammable Material Limits, Trained personnel, SOPs	U 8	NA	Building design, Cask/ canister design	Flammable Material Limits, Trained personnel, Fire Department, Transient Combustible Control Program, First Responders/ portable fire extinguishers	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TB-3	E-3	Radiological release due to overturned cask railcar or truck. Location: Transfer Bay Hazard Source: SNF Assembly	Cask car derails or truck accident overturns cask damaging a fuel assembly	Vehicle design, Track design	SOPs; Trained personnel, Site speed limits	U 2	NA	Cask/canister design	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1 % of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TB-4	E-3	Radiological release due to damage resulting from mishandling of SNF assembly. Location: Transfer Bay Hazard Source: SNF Assembly	Worker error; SNF assembly dropped, pierced, or otherwise damaged by crane, truck, or forklift.	Cask/canister design	SOPs, Trained personnel, Hoisting and Rigging Program, Crane preventive maintenance	A 3	NA	Cask/container design, Building Design, HVAC design,	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-4, Hazard Evaluation Table for L-Experimental Facility Receiving Area Transfer Bay, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TB-5	E-3	Radiological release due to damage resulting from object falling from overhead. Location: Transfer Bay Hazard Source: SNF Assembly	Aging structures in overhead (e.g. crane components, light fixtures, sprinkler piping, pipe hangers, degraded concrete).	Cask/container design, Building design, Concrete strength, Crane design	SOPs; Trained personnel, Preventive Maintenance Program	U 4	NA	Cask/Canister design	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TB-6	E-3	Radiological release due to loss of confinement. Location: Transfer Bay Hazard Source: SNF Assembly	Thermal stress, corrosion, breach of confinement, confinement mechanical damage	Canister design	SOPs; Trained personnel	A 5	NA	Building design; Canister design; Building HVAC system, Radiation monitors/ alarms	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA
TB-7	E-4	Direct radiological exposure of workers to SNF radiation. Location: Transfer Bay Hazard Source: SNF Assembly	Worker error; loss or lack of shielding	Canister/ Shielding design	SOPs (Fuel/Cask handling requirements); Trained personnel, Radiation Protection Program	A 3	U 3	Shielding design; Radiation monitors / alarms	Trained personnel; Radiation Protection Program	Onsite 1: High Onsite 2: Low Offsite: Negligible Assumes 1 MURR involved.	Onsite 1: Low Onsite 2: Neg Offsite: Neg	1 3 12	6 12 12

Table D-4, Hazard Evaluation Table for L-Experimental Facility Receiving Area Transfer Bay, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TB-8	E-6	Release of radiological material due to an external fire Location: Transfer Bay Hazard Source: SNF Assembly	External fire; forest/brush fire, fire from external vehicle Unknown ignition source	Vehicle design, Cask/canister design	Groundskeeping, Transient Combustible Control Program, Vehicle preventive maintenance, Trained personnel	A 1	EU 5,8	Building design; Cask/canister design	EOPs; Trained personnel; Transient Combustible Control Program, Fire Department / Forest Service	Onsite 1: High Onsite 2: High Offsite: Negligible Assumes 1 MURR involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	1 1 12	9 9 12
TB-9	E-6	Release of radiological material due to an external explosion. Location: Transfer Bay Hazard Source: SNF Assembly	External explosion, vehicle fuel tank, tanker truck high pressure gas storage cylinders	Vehicle design; Gas bottle design,	Preventive maintenance (vehicle), SOPs, Trained personnel	U 1,5	NA	Building design; Cask/canister design, Building Fire suppression system	Trained personnel, Transient Combustible Control Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TB-10	E-6	Damage to SNF assembly from aircraft impact event resulting in release of radiological material. Location: Transfer Bay Hazard Source: SNF Assembly	Helicopter impact	Building Design (Target area profile), Aircraft Design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	EU 6	BEU 10	Building Design Cask/canister design	Trained personnel	Onsite 1: High Onsite 2: High Offsite: Negligible Assumes 1 MURR involved.	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	7 7 12	11 11 11

Table D-4, Hazard Evaluation Table for L-Experimental Facility Receiving Area Transfer Bay, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TB-11	E-6	Damage to SNF assembly from aircraft impact event resulting in release of radiological material. Location: Transfer Bay Hazard Source: SNF Assembly	Airplane impact	Building Design (Target area profile), Aircraft Design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	BEU 2	NA	Building Design Cask/canister design	Trained personnel	Onsite 1: High Onsite 2: High Offsite: Negligible Assumes 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	10 10 11	NA NA NA
TB-12	E-7	Release of radiological material due to SNF damage from earthquake. Location: Transfer Bay Hazard Source: SNF Assembly	Earthquake (PC-2), loss of structural support, falling debris, confinement failure.	Building design	None	U 7	NA	Building design; Cask/canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TB-13	E-7 E-1	Earthquake followed by fire Location: Transfer Bay Hazard Source: SNF Assembly	Earthquake (PC-2), loss of structural support, falling debris, confinement failure. Ignition source, unknown.	Building Design, Canister design	Transient Combustible Control Program	U 7	EU 9	Building design; Canister design; Fire suppression system	EOPs; Trained personnel; Transient Combustible Control Program, Fire Department	Onsite 1: High Onsite 2: High Offsite: Negligible Assumes 1 MURR involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	4 4 12	9 9 12

Table D-4, Hazard Evaluation Table for L-Experimental Facility Receiving Area Transfer Bay, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TB-14	E-7	Release of radiological material due to SNF damage from tornado. Location: Transfer Bay Hazard Source: SNF Assembly	Tornado (PC-2) (BDBE -Tornado analysis not required for a PC-2 structure)	Building design, Cask/Canister design	Severe weather operating restrictions	EU 7	NA	Building design, Cask/canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	9 12 12	NA NA NA
TB-15	E-7	Release of radiological material due to SNF damage from high winds. Location: Transfer Bay Hazard Source: SNF Assembly	High velocity straight winds. (PC-2)	Building design, Cask/Canister design	Severe weather operating restrictions	A 7	NA	Building design, Cask/canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 1 MURR involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA
TB-16	E-7	Release of radiological material due to SNF damage from lightning strike. Fuel is partially vaporized Location: Transfer Bay Hazard Source: SNF Assembly	Direct lightning strike.	Building design, Lightning protection system	Severe weather operating restrictions	EU 7	EU 7	Building design Cask/canister design	EOPs; Trained personnel	Onsite 1: High Onsite 2: High Offsite: Negligible Assumes 1 MURR involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	7 7 12	9 9 12

Table D-4, Hazard Evaluation Table for L-Experimental Facility Receiving Area Transfer Bay, Unmitigated/Mitigated Consequences (continued)

Notes / References for Frequency Levels:

1. WSRC-TR-94-0188, Fire Risk Assessment Methodology Generic Event Tree Description
2. WSRC-RP-95-915, SRS Hazards Analysis Generic Initiator Database
3. WSRC-TR-93-581 and engineering judgement.
4. Frequency based on actual concrete ceiling degradation from C-Reactor operational history.
5. Engineering judgement
6. WSRC-RP-95-915 and the area square footage yield a helicopter impact frequency of "EU."
7. WSRC-TM-95-1, SRS Engineering Standards Manual
8. Initiator frequency for truck fire/explosion based on S-CLC-K-00147 and engineering judgement.
9. Frequency derived from WSRC-TR-2000-000479 and engineering judgement.
10. WSRC-TR-95-0054, Rev. 2 and engineering judgement.

Table D-5, Hazard Evaluation Table for L-Experimental Facility - Dry Cave Area, Unmitigated/Mitigated Consequences

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
DC-1	E-1	Radiological release due to a fire. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Power tool electrical short, friction or thermal ignition source, combustible in Ingot Storage & Monitoring	Electrical Equipment design codes; NFPA Standards	Transient Combustible Control Program; Trained personnel; SOPs	A 1	U 8	Building design; Building HVAC system, Canister/cask design	EOPs; Trained personnel; Transient Combustible Control Program, Fire Department, First Responders with portable fire extinguisher	Onsite 1: High Onsite 2: High Offsite: Low Assumes 6 ingots & 2 SNF assemblies involved. (7 MURR equivalent)	Onsite 1: Low Onsite 2: Low Offsite: Neg	1 1 3	6 6 12
DC-2	E-2	Radiological release due to an explosion. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Hydrogen evolved in forklift battery or test canister storage. Ignition source:, forklift, electrical circuits, other.	Battery design; Test canister design	SOPs, Trained personnel, Preventive maintenance (on forklift); H_2 monitoring of canister, Flammable Material Limits.	U 2	NA	Building design; Test canister design; Fire suppression equipment, Building HVAC system	Flammable Material Limits, Trained personnel, Fire Department, Transient Combustible Control Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 6 ingots & 1% of 2 SNF assemblies involved. (1% of 7 MURR equivalent)	Onsite 1: TBD Onsite 2: TBD Offsite: TBD	6 12 12	NA NA NA
DC-3	E-3	Radiological release due to damage resulting from mishandling of ingots. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Worker error; SNF ingots dropped, pierced, or otherwise damaged by truck or forklift.	Cask/canister design; Forklift / truck design	SOPs; Trained personnel, Hoisting and Rigging Program	A 3	NA	Building design; Cask/canister design; Building HVAC system	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1 % of 4 MURR ingots involved.	Onsite 1: TBD Onsite 2: TBD Offsite: TBD	3 12 12	NA NA NA

Table D-5, Hazard Evaluation Table for L-Experimental Facility - Dry Cave Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
DC-4	E-3	Radiological release due to damage resulting from object falling from overhead. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Aging structures in overhead (e.g. light fixtures, sprinkler piping, pipe hangers, degraded concrete).	Building design, Concrete strength, Cask/container design	Periodic inspections; Preventive maintenance	U 4	NA	Building design; Container design; Building HVAC system	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1 % of 4 MURR ingots involved.	Onsite 1: TBD Onsite 2: TBD Offsite: TBD	6 12 12	NA NA NA
DC-5	E-3	Radiological release due to loss of confinement. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Thermal stress, corrosion, breach of confinement, confinement mechanical damage	Canister design; Ingot final condition	SOPs; Trained personnel	A 5	NA	Building design; Canister design; Building HVAC system,	Trained personnel, Radiation Protection Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 MURR ingots involved.	Onsite 1: TBD Onsite 2: TBD Offsite: TBD	3 12 12	NA NA NA
DC-6	E-4	Direct radiological exposure of workers to SNF radiation. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Worker error; loss or lack of shielding	Canister/ Shielding design	SOPs (Canister handling procedures); Trained personnel, Radiation Protection Program	A 3	U 3	Shielding design; Radiation monitors / alarms	Trained personnel; Radiation Protection Program	Onsite 1: High Onsite 2: Low Offsite: Negligible Assumes 1 or more ingots involved. Assume >2000R/hr @1 ft per ingot	Onsite 1: Low Onsite 2: Neg Offsite: Neg	1 3 12	6 12 12

Table D-5, Hazard Evaluation Table for L-Experimental Facility - Dry Cave Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
DC-7	E-5	Nuclear Criticality due to organization of critical mass or addition of moderator. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Worker error, flooding	Storage Configuration design, Canister design, Building design	Criticality Control Program, SOPs, Trained personnel	U 2,3	BEU 9	Building design	EOPs; Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assumes 6 ingots & 2 SNF assemblies involved. (7 MURR equivalent)	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	4 4 6	11 11 11
DC-8	E-6	Radiological release due to an external fire. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	External Fire; forest/brush fire, external vehicle fire	Vehicle design; Building Design; Canister Design	Groundskeeping, Vehicle preventive maintenance, Trained personnel, Transient Combustible Control Program, Fire Department / Forest Service	A 1	EU 5,10	Building design; Canister design	EOPs; Trained personnel; Transient Combustible Control Program, Fire Department / Forest Service	Onsite 1: High Onsite 2: High Offsite: Low Assumes 6 ingots & 2 SNF assemblies involved. (7 MURR equivalent)	Onsite 1: Low Onsite 2: Low Offsite: Neg	1 1 3	9 9 12
DC-9	E-6	Release of radiological material due to an external explosion. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	External explosion, vehicle fuel tank, tanker truck high pressure gas storage cylinders	Vehicle design; Gas bottle design	Preventive maintenance (vehicle), SOPs, Trained personnel	U 1,5	NA	Building design; Canister design, Building Fire suppression system	Trained personnel, Transient Combustible Control Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1 % of 6 ingots & 1 % of 2 SNF assemblies involved. (1% of 7 MURR equivalent)	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA

Table D-5, Hazard Evaluation Table for L-Experimental Facility - Dry Cave Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
DC-10	E-6	Damage to SNF ingots from aircraft impact event resulting in release of radiological material. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Helicopter impact	Building Design (Target area profile), Aircraft Design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	EU 6	BEU 11	Building design; Canister design	Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assumes 6 ingots & 2 SNF assemblies involved. (7 MURR equivalent)	Onsite 1: Neg Onsite 2: Neg Offsite: Neg	7 7 9	11 11 11
DC-11	E-6	Damage to SNF ingots from aircraft impact event resulting in release of radiological material. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Airplane impact	Building Design, Aircraft Design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	BEU 2	NA	Building design; Canister design	Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assumes 6 ingots & 2 SNF assemblies involved (7 MURR equivalent).	Onsite 1: NA Onsite 2: NA Offsite: NA	10 10 10	NA NA NA

Table D-5, Hazard Evaluation Table for L-Experimental Facility - Dry Cave Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
DC-12	E-7	Release of radiological material due to SNF damage from earthquake. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Earthquake (PC-2), loss of structural support, falling debris, confinement failure.	Building design	None	U 7	NA	Building design; Canister design, Building HVAC design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1 % of 6 ingots & 1% of 2 SNF assemblies involved. (1% of 7 MURR equivalent)	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
DC-13	E-7	Earthquake followed by fire Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Earthquake (PC-2), loss of structural support, falling debris, confinement failure. Unknown ignition source.	Building design	Transient Combustible Control Program	U 7	EU 12,13	Building design; Canister design	EOPs; Trained personnel; Transient Combustible Control Program, Fire Department	Onsite 1: High Onsite 2: High Offsite: Low Assumes 6 ingots & 2 SNF assemblies involved. (7 MURR equivalent)	Onsite 1: Low Onsite 2: Low Offsite: Neg	4 4 6	9 9 12
DC-14	E-7	Release of radiological material due to SNF damage from tornado. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Tornado (PC-2) (BDBE -Tornado analysis not required for a PC-2 structure)	Building design	None	EU 7	NA	Building design; Canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 6 ingots & 1% of 2 SNF assemblies involved. (1 % of 7 MURR equivalent)	Onsite 1: NA Onsite 2: NA Offsite: NA	9 12 12	NA NA NA

Table D-5, Hazard Evaluation Table for L-Experimental Facility - Dry Cave Area, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
DC-15	E-7	Release of radiological material due to SNF damage from high winds. Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	High velocity straight winds. (PC-2)	Building design	None	A 7	NA	Building design; Canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 6 ingots & 1% of 2 SNF assemblies involved. (1% of 7 MURR equivalent)	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	TBD TBD TBD
DC-16	E-7	Release of radiological material due to SNF damage from lightning strike. Ingots are partially vaporized Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Lightning strike to facility.	Building design; Lightning protection	None	EU 7	EU 7	Building design; Canister design	EOPs; Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assumes 4 ingots involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	7 7 9	9 9 9
DC-17	E-7	Flooding spreads contamination from ingots Location: Ingot Storage & Monitoring Hazard Source: SNF ingots, SNF assemblies	Heavy rain, external flooding.	Building design; Building location / elevation	Inspection /maintenance of area storm drains	U 2,7	NA	Building design; Canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 6 ingots & 2 SNF assemblies involved. (7 MURR equivalent)	Onsite 1: TBD Onsite 2: TBD Offsite: TBD	6 12 12	NA NA NA

Table D-5, Hazard Evaluation Table for L-Experimental Facility - Dry Cave Area, Unmitigated/Mitigated Consequences (continued)

Notes / References for Frequency Levels:

1. WSRC-TR-94-0188, Fire Risk Assessment Methodology Generic Event Tree Description
2. WSRC-RP-95-915, SRS Hazards Analysis Generic Initiator Database and engineering judgement.
3. WSRC-TR-93-581 and engineering judgement.
4. Frequency based on actual concrete ceiling degradation from C-Reactor operational history.
5. Engineering judgement
6. WSRC-RP-95-915 and the area square footage yield a helicopter impact frequency of "EU."
7. WSRC-TM-95-1, SRS Engineering Standards Manual
8. Frequency derived from WSRC-TR-99-00047 and engineering judgement.
9. N-NCS-L-00010 and engineering judgement.
10. Initiator frequency for truck fire/explosion based on S-CLC-K-00147 and engineering judgement.
11. WSRC-TR-95-0054, Rev. 2 and engineering judgement.
12. Seismic induced fire frequency for PWDIs from S-CLC-K-00128.
13. Frequency derived from WSRC-TR-99-00047 and engineering judgement.

Table D-6, Hazard Evaluation Table for L-Experimental Facility - Transportation, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TR-1	E-1	Radiological release due to a fire. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Truck fire or external fire. Truck/power tool electrical short, friction or thermal ignition source. Truck fuel, combustibles in Truck,	Vehicle design, Cask/canister design	Trained driver; SOPs; Preventive maintenance (vehicle)	U 1	EU 1,4	Portable fire extinguisher; Cask/canister design	EOPs; Trained personnel; Fire Department	Onsite 1: High Onsite 2: High Offsite: Low Assumes 4 ingots involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	4 4 6	9 9 12
TR-2	E-2	Radiological release due to an explosion. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Truck fuel, hydrogen evolved in truck battery. Ignition source: truck, other.	Battery design; Vehicle design	Trained drivers. Preventive maintenance (vehicle)	U 1	NA	Cask/canister design	Trained personnel, Fire Department	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TR-3	E-3	Radiological release due to overturned truck. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Truck accident overturns cask damaging the fuel assembly or ingots	Vehicle design, Road design	SOPs; Trained drivers, Driver Drug/Alcohol testing, Speed Limits, Posted vehicle warning signs	U 2	NA	Cask/canister design	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TR-4	E-3	Radiological release due to loss of confinement. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Thermal stress, corrosion, breach of confinement, confinement mechanical damage	Cask/canister design	SOPs; Trained personnel, Inspection programs	A 4	NA	Cask/canister design	Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA

Table D-6, Hazard Evaluation Table for L-Experimental Facility - Transportation, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TR-5	E-4	Direct radiological exposure of workers to SNF radiation. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Worker error; loss or lack of shielding	Cask/canister shielding design	Preventive maintenance; SOPs Cask handling/transportation procedures); Radiation Protection Program	A 3	U 3	Cask/canister shielding design	Trained personnel; Radiation Protection Program	Onsite 1: High Onsite 2: Low Offsite: Negligible Assumes 4 ingots involved. Assume >2000 R/hr per ingot @1 ft.	Onsite 1: Low Onsite 2: Neg Offsite: Neg	1 3 12	6 12 12
TR-6	E-6	Release of radiological material due to an external explosion. Location: Truck Transport Hazard Source: Ingots, fuel assembly	External explosion, vehicle fuel tank, tanker truck high pressure gas storage cylinders	Vehicle design; Cask/canister design; Gas bottle design	Preventive maintenance (other government vehicles), pressure limits on storage cylinders	U 1	NA	Cask/canister design	Trained personnel; Radiation Protection Program	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA
TR-7	E-6	Radiological Release due to an external fire Location: Truck Transport Hazard Source: Ingots, fuel assembly	Forest fire; brush fire, building fire, other vehicle fire	Vehicle design, Cask canister design	Groundskeeping; Preventive maintenance (other government vehicles)	U 1	EU 1,4	Cask/canister design	EOPs; Trained personnel; Fire Department / Forest Service	Onsite 1: High Onsite 2: High Offsite: Low Assumes 4 ingots involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	4 4 6	9 9 12

Table D-6, Hazard Evaluation Table for L-Experimental Facility - Transportation, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TR-8	E-6	Damage to ingots from aircraft impact event resulting in release of radiological material. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Helicopter impact	Truck Design (Small target area profile), Aircraft Design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	EU 5	BEU 4	Cask/container design	ERPs, Trained personnel, Fire Department	Onsite 1: High Onsite 2: High Offsite: Low Assumes 4 ingots involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	7 7 9	10 10 11
TR-9	E-6	Damage to Ingots from aircraft impact event resulting in release of radiological material. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Airplane impact	Aircraft Design	Trained Pilots, SRS flight restrictions, Preventive maintenance (aircraft)	BEU 2	NA	Cask/container design	Trained personnel, Fire Department	Onsite 1: High Onsite 2: High Offsite: Low Assumes 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	10 10 10	NA NA NA
TR-10	E-7	Release of radiological material due to SNF damage from earthquake. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Earthquake, falling debris, confinement failure.	None	None	U 4	NA	Cask/canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	6 12 12	NA NA NA

Table D-6, Hazard Evaluation Table for L-Experimental Facility - Transportation, Unmitigated/Mitigated Consequences (continued)

Event No.	Event Category	Postulated Event Description	Causes	Prevention Features		Initiating Event Freq. Level		Mitigation Features		Consequence Level		Risk Rank	
				Design	Administration	Unmitigated	Mitigated	Design	Administration	Unmitigated Consequence	Mitigated Consequence	Unmitigated	Mitigated
TR-11	E-7	Release of radiological material due to SNF damage from tornado. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Tornado	Cask/canister design	Severe weather operating restrictions	EU 4	NA	Cask/canister design	EOP's, Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	9 12 12	NA NA NA
TR-12	E-7	Release of radiological material due to SNF damage from high winds. Location: Truck Transport Hazard Source: Ingots, fuel assembly	High velocity straight winds.	Cask/canister design	Severe weather operating restrictions	A 4	NA	Cask/canister design	EOPs; Trained personnel	Onsite 1: Low Onsite 2: Negligible Offsite: Negligible Assumes 1% of 4 ingots involved.	Onsite 1: NA Onsite 2: NA Offsite: NA	3 12 12	NA NA NA
TR-13	E-7	Release of radiological material due to SNF damage from lightning strike. SNF is partially vaporized. Location: Truck Transport Hazard Source: Ingots, fuel assembly	Direct lightning strike	None	Severe weather operating restrictions	EU 4	EU 4	Cask/canister design, truck rubber tires	EOPs; Trained personnel	Onsite 1: High Onsite 2: High Offsite: Low Assumes 4 ingots involved.	Onsite 1: Low Onsite 2: Low Offsite: Neg	7 7 9	9 9 12

Table D-6, Hazard Evaluation Table for L-Experimental Facility - Transportation, Unmitigated/Mitigated Consequences (continued)

Notes / References for Frequency Levels:

1. Initiator frequency for truck fire/explosion based on S-CLC-K-00147 and engineering judgement
2. WSRC-RP-95-915, SRS Hazards Analysis Generic Initiator Database
3. Derived from WSRC-TR-93-581 and engineering judgement.
4. Engineering judgement
5. WSRC-RP-95-915 and the area square footage yield a helicopter impact frequency of "EU."

APPENDIX E

CONSEQUENCE DERIVATION

Unmitigated Event Consequence Derivation, Assumptions and Notes

General

Using source terms calculated on a unit MURR release basis, doses were determined using the MACCS computer code for the first seven of eight events shown in Table E-1 (extracted from CalcNote S-CLC-00012, Ref. 18). The first seven accidents listed in Table E-1 involve one MURR assembly (150 MWD with 150 day cooling) as the Material at Risk (MAR) in a molten state, and are considered to be the bounding events in respect to consequence. The eighth event in Table E-1 involves a fire which consumes the 8 contaminated deionizer resin vessels stored adjacent to the LEF. For this Deionizer Fire event, dose was estimated by a hand calculation using information from Reference 20 and RADScreen (Ref. 28) for this HA.

Effective Dose Equivalent (EDE) values are provided in REM for each event in both filtered and/or unfiltered releases using a 3 minute release duration. LPFs were established at 1.0 for all events. ARF and RF values for the nuclides of concern have been applied to determine the doses from these events with the exception of the Bounding Total Release event and Deionizer Fire event for which no ARF and RF values were applied. For this unmitigated Hazards Analysis, only the unfiltered events were considered. The filtered release events in Table E-1 are included for comparative informational purposes only.

The respective dose to both the Maximally-exposed Offsite Individual (MOI) and the Onsite 2 worker (at 100m) are provided in Table E-1. The doses to the Onsite 1 facility worker (a worker in the immediate vicinity of the event) are not listed in Table E-1. The Onsite 1 worker dose for each event was evaluated qualitatively using analytical experience and judgment. Typically the Onsite 1 worker dose was increased one consequence level relative to the applicable calculated Onsite 2 worker (100m) dose.

Table E-1, Selected MACCS Modeled Accident Consequences in REM

Selected Event	EDE from 3 min. Release		
	100 m		MOI
Bounding Total Release (BT)*	2.2E+03		5.0E+00
Steam Explosion, No Filter (SE)	1.1E+03		2.4E+00
Steam Explosion (With HEPA)	1.1E+01		3.2E-02
Extreme Overheat Transient, No Filter (EO)	1.0E+02		2.0E-01
Extreme Overheat Transient (w/Filter)	1.0E+00		2.6E-03
Moderate Overheat Transient, No Filter (MO)	2.2E+01		4.0E-02
Moderate Overheat Transient (w/Filter)	2.8E-01		4.0E-04
Loss of Filter No Overheat (LF)	2.4E+00		3.9E-03
Molten Spill No Filter (MS)	2.1E+01		3.3E-02
Molten Spill (With Filter)	1.5E-01		4.4E-04
Normal Operation No Filter (NO)	2.2E+00		3.3E-03
Normal Operation (With Filter)	1.5E-02		4.3E-05
Deionizer Fire* (8 deionizers) (DF)**	8.20E+01		3.00E-02

* 100% release. No ARF x RF.

** Deionizer Fire event performed by manual calculation using Reference 20 and RADScreen (Ref. 28).

Many types of events postulated in this HA do not have directly corresponding consequences that were explicitly modeled in Table E-1 (e.g. fire, criticality, etc.). In cases such as these, the consequence of the modeled event that was most closely related to the event under consideration was used as a reference dose. For example, to determine the consequences for a fire event, the dose given by the Extreme Overheat Transient without filter, (EO) in Table E-1, was multiplied by the MAR for the affected facility section.

In cases where there was not a modeled event in Table E-1 which was closely related to the event under consideration, the radiological dose was determined by using an appropriate ARF x RF value (from DOE HDBK-3010-94, Ref. 22) applied to the Bounding Total Release (BT) event dose from Table E-1. In other instances, to obtain dose estimates other qualitatively determined values were used which were dependent on the event energy under consideration and the physical form of the material.

For example, the consequence of an event involving a solid, treated SNF ingot dropped by a crane is not appropriately represented by any of the molten event doses modeled in Table E-1. To estimate the consequences of this dropped ingot event, the Bounding Total Release event (BT) dose was reduced with a DR x ARF x RF = 1.0E-5, where a DR = 1% of the ingot was used to represent the quantity of surface contamination or material that is jarred loose from the ingot on impact, and an ARF x RF = 1.0E-3 selected from Section 5.1 of DOE-HDBK-3010-94 (Ref. 22). The selected ARF x RF value used the bounding value of the "Free-Fall Spill and Impaction Stress" for contaminated, combustible solids which strongly impact the floor (Ref. 22, p. 5-3 and 5-4).

Event Consequences Derivation Data Summary Table

Table E-3, provides a summary of the values used to arrive at consequences for each event. Values in the table include: Event Category, Frequency, MAR Available, Effective MAR, ARF x RF, Reference Dose from Table E-1, and Consequence for each event. The Event Category follows the HA event categorization outline as presented in Table A-2 in Appendix A for Fires, Explosions, etc. The MAR Available is the maximum material at risk available per facility section as listed in Table C-2 from Appendix C. The Effective MAR is that material expected to be directly impacted by the event (MAR x DR). In the ARF x RF column of Table E-3, a value is listed for each event that uses the Bounding Total release (BT) or Deionizer Fire (DF) dose from Table E-1 as an initial bounding reference dose for which no ARF x RF value was previously applied. These ARF x RF value was determined using bounding values from DOE-HDBK-3010-94 (Ref. 22). Where the ARF x RF is listed as "N/A" in Table E-3, this indicates that an ARF x RF value was previously factored into the event source term to arrive at the dose listed in Table E-1 (See Refs.4 and 18). In general, an "N/A" was listed in the ARF x RF column for all HA events using the dose indicated for the Steam Explosion (SE), Extreme Overheat (EO), Loss of Filter (LF), Molten Spill (MS), and Normal Operation No Filter (NO) events from Table E-1. The Reference Dose column in Table E-3 lists a 2-letter code for the modeled event dose from Table E-1 from which the specific HA event dose is derived. The Consequence column lists the resulting consequences for the event: High (H), Moderate (M), Low (L), or Negligible (N) for the three receptor points Onsite 1, Onsite 2, and Offsite. A Leak Path Factor (LPF) = 1.0 was assumed for all events due to the unmitigated nature of this analysis. No credit is given to the building in impeding any release leak path.

Consequence Assumptions by Event Category (E-1 through E-7)

E-1 Fire

Area fires were postulated for each facility section. It was generally assumed that both combustibles and ignition sources are available in each section. Based on historical data, unmitigated fires are considered "Anticipated" in frequency, with the exception of fires initiated by some other event, such as an earthquake, in which case the frequency of the initiating event is adopted.

In general for this analysis, an unmitigated fire event is assumed to sustain temperatures sufficient to involve or consume all MAR within the respective facility section where the fire initiates. The radiological release due to a fire is assumed to result in an EDE represented by the unfiltered Extreme Overheat Transient (EO) presented in Table E-1, multiplied by the number of MURR assemblies or ingots assumed to be present in the section inventory.

Additionally, for fire events affecting the Furnace Area (FA-1, 2, 27,34), the 8 deionizer vessels stored in the purification cells within the Purification Wing adjacent to the trailer space are included as part of the consumed inventory. The Deionizer Fire (DF) event dose from Table E-1 was applied (assumes an inventory of all 8 deionizers) to the consequence to include the component of dose which could be attributed to these vessels during a fire event.

E-2 Explosion

Postulated explosion events were of two types: explosions/deflagrations due to ignition of flammable or explosive vapors, and pressure waves due to the rupture of high pressure, nonflammable systems. Explosion event damage was assumed based on the pressure wave and /or fragmentation damage alone. A fire was not assumed to follow either type of explosion event. A fire following an explosion would be bounded by the previously-addressed Fire Event for solid inventory. Explosions are assumed to impact the MAR (inventory) only in the respective sections where the event occurs.

For the purposes of this analysis, an explosion of either type was conservatively assumed to release 1% of a solid ingot or untreated SNF assembly, This percentage is assumed to be represented by that material contained within a 1/100 inch thick surface contamination layer surrounding the ingot. Explosion events (other than the Steam Explosion event) were not modeled in Table E-1. To estimate the consequences of these explosion events (e.g. FA-3), the Bounding Total Release (BT) event from Table E-1 was multiplied by the appropriate effective inventory, and an ARF x RF = 1.0E-3 was applied (DOE-HDBK-3010-94, Ref. 22, Venting of Pressurized Gases over Contaminated, Combustible Wastes, and Free Fall Spill and Impaction Stresses for Contaminated, Combustible Solids, p. 5-3, 5-4).

Additionally, a steam explosion event, in which a rapid generation of steam is produced in the furnace due to the accidental introduction of water into the melt, is represented by event FA-4. The Steam Explosion (SE) event with no filter, as presented in Table E-1, was used in the dose consequence multiplied by a MAR of 1.5 MURR (1 MURR molten in the furnace and 0.5 MURR assumed to exist in the offgas system).

E-3 Loss of Containment or Confinement

In general, accidents within this category involve the breach or rupture of a primary confinement allowing the release of contained radioactive particulates or gases. The events typically involve the dropping or other accidental mishandling of these items or containers of MAR either by material failure, mechanical or control system failure, worker error or impact, such that the physical structure or container of the MAR is breached.

In this unmitigated analysis, no credit is intended for any confinement other than the structure of the material itself in its physical form. For example, an SNF assembly or a treated SNF ingot are forms of MAR which inherently provide their own primary confinement (below 500 degrees Celsius). In the case of a furnace crucible that contains molten SNF, an offgas absorber bed container, ingot canisters, or transportation casks, the respective container is credited with only enough structure to allow minimal grouping or carrying of the material within, and otherwise offers no protection from hazards.

An event involving a solid, treated SNF ingot dropped by a process crane is not directly represented by any of the molten events presented in Table E-1. To determine the consequences of this event, an effective MAR of 1% was used to represent the quantity of surface contamination or material that is jarred loose from the ingot. The 1% surface material is based on a surface material 0.01 inches thick on a cylindrical ingot 6.75 inches in diameter by 8 inches high. An ARF x RF = 1.0E-3 (DOE-HDBK-3010-94, Ref. 22, Free Fall Spill and Impaction Stress for Contaminated Combustible Solids, p.5-4) was then applied to the Bounding Total release (BT) event dose to arrive at the estimated consequence. A similar semi-quantitative method was used for all events represented by a relatively low energy deformation or breach involving a SNF assembly or a treated SNF ingot dropped or otherwise mishandled.

The consequence of the crucible failure and molten spill event, FA-14, is directly represented by the modeled unfiltered Molten Spill event given in Table E-1. The assumed MAR involves one crucible batch.

Postulated offgas system accidents include: a total loss/lack of offgas (FA-19) confinement, leaks in the offgas system due to improper installation of a filter or filter material failure (FA-20), and a breach of a radioactively loaded filter (FA-13, 14) during replacement. The loss/lack of offgas treatment event (FA-19) was modeled with the Loss of Filter (LF) event dose and uses an inventory of 1.5 MURR to account for the material assumed to exist in the offgas system (0.5 MURR) and the offgas evolving from the melt (1.0 MURR). The leaking filter event (FA-20) also uses the Loss of Filter (LF) consequence but with an effective MAR of 1% of the material in the crucible and the offgas system. The breached filter events (FA-13, 14) affects an inventory of 0.5 MURR assumed to exist in the removed filter with an ARF x RF = 1.0E-2 applied to the Bounding Total Release (BT) event dose (DOE-HDBK-3010-94, Free Fall Spill and Impaction Stresses on an unenclosed HEPA filter, p.5-8).

The offgas system failure event (FA-21) due to loss of fans uses the unfiltered Normal Operation event (NO) dose in Table E-1. The consequence uses an inventory of 1.5 MURR to conservatively account for the release of all evolved offgas from the melt (1.0 MURR) combined with the residual material assumed to exist in the offgas system (0.5 MURR).

An overtemperature event in the furnace is represented by events FA-17 and 18. During this accident the furnace is assumed to reach a temperature over 2000 degrees C (Ref. 4). The dose from this event is directly modeled in Table E-1 as the Extreme Overheat event (EO). An inventory of 1.5 MURR was used to account for the release of excess offgas in the melt (1.0 MURR) combined with an assumed release from the damaged filters and offgas system (0.5 MURR).

Accidents involving solidified samples from the furnace melt are assumed to consist of 15/1000 of one MURR ingot (0.015 of an ingot) of MAR due to the anticipated size of the sample relative to a full ingot. This volume represents a cylindrical sample conservatively assumed to be approximately 5 inches long by 1 inch in diameter.

E-4 Direct Radiological Exposure

In a true unmitigated hazard analyses where no shielding or remote operation is credited, direct radiological exposure of facility workers to SNF assemblies, ingots and loaded filters would tend to bound the majority of events and would result in a consequence of "High" to the Onsite 1 receptor category in nearly every event. In this unmitigated analysis, a method is necessary to address this ever-present hazard due to direct radiation exposure, while still allowing differentiation of the hazards associated with event-specific respirable uptake which might otherwise be overshadowed by the high direct radiation dose. As such, in this analysis, the direct radiation exposure dose component is disregarded in all non-E-4 events to allow the dose component due to respirable release uptake to be emphasized. To address the hazard associated with direct radiation exposure at least one loss/lack of shielding event (event category E-4) is included in each facility section Hazard Evaluation table (Appendix D).

Postulated events involving direct radiological exposure of facility workers were developed for each facility section where exposure to radiological inventory could occur. For this unmitigated Hazards Analysis, it was assumed that all direct radiological exposures were "Anticipated" in frequency due to the fact that no credit is given for shielding in an unmitigated analysis. Due to the high radiation fields (estimated >2,000 R/hr at 1 ft. as derived from Ref. 19) emitted by treated and untreated SNF and filters, consequences of "High" were assumed for the Onsite 1 worker immediately adjacent to the hazard. Consequences of "Low" were assigned to the Onsite 2 worker (100 m) and "Negligible" to the Offsite public due to the distances from the hazard source.

E-5 Nuclear Criticality

All postulated criticality accidents are unmitigated with no credit given for the double-contingency principle. Typically, criticality events are categorized as "Unlikely" in frequency due to the series of combined events which must occur to position the required quantity of fissile material in a geometry favorable to criticality.

Postulated criticality events consequences are assumed to be adequately represented by the doses provided for the unfiltered Extreme Overheat Transient (EO) in Table E-1. The dose was multiplied by the MURR units of inventory assumed to be involved for each criticality event.

E-6 External Hazards

For the series of external surface vehicle, external crane drop, train derailment, and aircraft impact events, the building is not credited in the unmitigated analysis. The applicable vehicles or loads are assumed to be able to travel unencumbered to impact what are normally considered interior areas.

As an example, for the surface vehicle (car, truck) (FA-29) event impacting the Furnace Area, 5 MURR of inventory are assumed to be impacted, 1 MURR is conservatively assumed to be molten in the crucible during furnace operations with 4 stored ingots (solid form) also impacted by the vehicle. The Molten Spill (MS) event dose is applied to the spilled crucible. The dose due to impact with the 4 solid ingots is based on the Bounding Total release (BT) dose with an applied ARF x RF = 1.0E-3 (Ref. 22, Section 5.1) and an effective MAR of 1% of each ingot, similar to the dropped ingot methodology described in E-3 above.

For the more energetic helicopter impact event to the Furnace Area (FA-31), a 5 MURR inventory is assumed to be affected. The consequences are based on the larger release associated with the unfiltered Extreme Overheat (EO) event to account for the increased energy and probable fire associated with an aircraft impact. For the airplane impact (FA-32), an inventory of 4 deionizers along with the 5 MURR is assumed to account for the probable longer impact area resulting from the increased horizontal velocities inherent with fixed-wing aircraft.

E-7 Natural Phenomena

In an unmitigated HA no credit is given for any seismic qualification of the building or components. Earthquake events are postulated both with and without subsequent fire events.

In the case of earthquakes without a resulting fire, shaking, falling, or breaching of some percentage of the solid (ingot or SNF assembly) inventory is assumed. In the furnace area earthquake event (FA-33), the furnace is conservatively assumed to be in operation during the event. The seismic motion breaks the crucible leading to a molten spill of 1 MURR. This component of the release uses the Molten Spill (MS) event dose from Table E-1. For the solid MAR, an ARF x RF = 1.0E-3 (Ref. 22, Section 5.1, Free Fall Spill and Impaction Stress of Contaminated Combustible Solids, p.5-4, similar to a dropped ingot event) was applied to the Bounding Total release (BT) consequence to represent the release of the surface contamination layer (1% of ingot volume and activity) that is conservatively assumed to coat the 4 ingots stored in the area. Additionally, the deionizers in the Purification Space are assumed to be affected. This release component of the event assumes the Deionizer Fire (DF) dose given in Table E-1 multiplied by an ARF x RF = 1.0E-3 (Ref. 22, Section 5.1, Free Fall Spill and Impaction Stress of Contaminated Combustible Solids, p.5-4) to an inventory of 8 deionizers.

The earthquake with fire accident is similar to the fire event as previously described in the E-1 section of Appendix E.

In the case of a tornado or high straight wind events, damage to treated and untreated solid SNF is possible due to wind-driven motion impact or damage from impact from external wind-driven missiles. In unmitigated scenarios, no credit is given for the building. As an example, for the

Furnace Area (events FA-35, 36), the event is conservatively assumed to upset the operating furnace causing a molten spill. The unfiltered Molten Spill (MS) event consequence from Table E-1 was used as the dose for the molten SNF material in the crucible. For damage to the solid inventory in the Furnace Area, the Bounding Total release (BT) event dose with an applied ARF x RF = 1.0E-3 (Ref.22, Sect 5.1, similar to dropped ingot event) was used to reflect the release of the contamination layer (assumed 1% of ingot volume and activity) on the 4 solid MURR ingots. Additionally, all 8 deionizers are assumed to be affected. The event consequences for this component of the event release were estimated using the Deionizer Fire (DF) event dose from Table E-1 with an applied ARF x RF = 1.0E-2 (derived from DOE-HDBK-3010-94, Ref. 22, Section 5.1, Free Fall and Impaction Stresses for HEPA filters and Venting of Pressurized Gases through Filters, Bounding values, p. 5-8).

In the unmitigated lightning strike events, no credit is given for the protection normally provided by a building. The event assumes a direct strike by lightning consuming the selected quantity of inventory as in a fire. The dose consequence for this event was modeled using the Extreme Overheat (EO) event from Table E-1. (example FA-37)

For flooding events (without criticality), water was assumed to flow over and around the MAR releasing any surface contamination to the flowing surface water. In general, consequences of "Low" for the Onsite 1 worker and "Negligible" for the Onsite 2 worker and Offsite public were qualitatively assumed for these events. (example FA-38)

Deionizer Fire Consequence Manual Calculation

Eight (8) deionizers containing contaminated resin are stored within the purification cells immediately adjacent to the LEF and could contribute to the radiological release from the LEF inventory in the event of a fire within the area. Since a source term and consequence from a fire involving these deionizer vessels was not developed in References 4 and 18 respectively, the calculation below conservatively estimates the radiological release from a fire consuming the contents of these vessels.

The assumed radiological inventory of each deionizer vessel is provided in Table E-2 based on information from Reference 20. The RADScreen spreadsheet used by the Hazards Analysis Group (Ref. 28) was used to conservatively estimate the dose in Table E-2 based on the curie content of each nuclide within the vessels. RADScreen provides dose in Rem per curie of a given nuclide for both the Offsite and Onsite 2 receptor based on a 3 minute duration atmospheric release. Dose estimates are given for assumptions of either No Deposition, or a 1 Centimeter/Second (cm/s) Deposition rate for the atmospheric release. In general, the No Deposition assumption yields a more conservative dose estimate for the Offsite receptor, while the 1 cm/s Deposition Rate yields a more conservative dose for the Onsite 2 receptor. The RADScreen dose per curie value for each nuclide is multiplied by the assumed curie content of the vessel to estimate the dose. The dose for all 8 deionizer contents being released in a fire is summarized at the bottom of the table. The most conservative values for the Offsite and Onsite 2 receptors in Table E-2 were subsequently transferred for use in Table E-1. Based on a comparison of events in Table E-1, a fire consuming all eight deionizer vessels is roughly equivalent in dose to the unfiltered Extreme Overheat event (fire) for one MURR assembly.

Table E-2, Dose Due to Deionizer Vessel Radionuclide Release (Fire)

Nuclide	Curies/ Deionizer	Dose Due to 100 % Release. No ARF x RF.							
		No Deposition				1 cm/s Deposition			
		Offsite		Onsite 2 (100m)		Offsite		Onsite 2 (100m)	
		Rem/Ci RADScreen	Dose Rem	Rem/Ci RADScreen	Dose Rem	Rem/Ci RADScreen	Dose Rem	Rem/Ci RADScree	Dose Rem
Tritium	120	5.00E-08	6.00E-06	2.20E-05	2.64E-03	5.00E-08	6.00E-06	2.20E-05	2.64E-03
C-14	20	1.31E-06	2.62E-05	4.53E-04	9.06E-03	7.90E-07	1.58E-05	6.10E-04	1.22E-02
Cs-137	2	2.10E-05	4.20E-05	7.30E-03	1.46E-02	1.80E-05	3.60E-05	1.10E-02	2.20E-02
Sr-90	3.2	1.50E-04	4.80E-04	5.20E-02	1.66E-01	9.10E-05	2.91E-04	7.00E-02	2.24E-01
Alpha	0.1	3.00E-01	3.00E-02	1.00E+02	1.00E+01	1.80E-01	1.80E-02	1.00E+02	1.00E+01
(Am-241)									
Total Dose/Deionizer			3.06E-02		1.02E+01		1.83E-02		1.03E+01
Dose for 8 Deionizers			**2.44E-01**		8.15E+01		1.47E-01		**8.21E+01**

Table E-3, Event Consequences Derivation Data Summary

Event	Category	Frequency	MAR Available in Section	Effective MAR MAR x DR	ARF x RF	Reference Dose from (Tab. E-1)	Consequence (On1, On2, Offsite)
Furnace Area							
FA-1	E-1	U	5 MURR/8 DEI	5 MURR	N/A	EO	HHL
				8 DEIONIZERS	N/A	DF	
FA-2	E-1	A	5 MURR/8 DEI	5 MURR	N/A	EO	HHL
FA-3	E-2	U	5 MURR/8 DEI	1% of 5 MURR	1.0E-03	BT	LNN
FA-4	E-2	A	5 MURR/8 DEI	1.5 MURR	N/A	SE	HHL
FA-5	E-2	U	5 MURR/8 DEI	1.0 MURR	N/A	SE	HHL
FA-6	E-3	A	5 MURR/8 DEI	4.0 MURR	estimated contamination dose		LNN
FA-7	E-3	A	5 MURR/8 DEI	1% of 1.5 MURR	1.0E-03	BT	LNN
FA-8	E-3	U	5 MURR/8 DEI	1% of 1.5 MURR	1.0E-03	BT	LNN
FA-9	E-3	A	5 MURR/8 DEI	1% of 1.5 MURR	1.0E-03	BT	LNN
FA-10	E-3	U	5 MURR/8 DEI	1% of 1.5 MURR	1.0E-03	BT	LNN
FA-11	E-3	U	5 MURR/8 DEI	1.0 MURR	N/A	MS	MMN
				0.5 MURR	N/A	LF	
FA-12	E-3	A	5 MURR/8 DEI	.015 MURR	N/A	MS	LNN
FA-13	E-3	A	5 MURR/8 DEI	0.5 MURR	1.0E-02	BT	MLN
FA-14	E-3	U	5 MURR/8 DEI	0.5 MURR	1.0E-02	BT	MLN
FA-15	E-3	A	5 MURR/8 DEI	1.0 MURR	N/A	MS	MLN
FA-16	E-3	A	5 MURR/8 DEI	1% of 1.0 MURR	1.0E-03	BT	LNN
FA-17	E-3	A	5 MURR/8 DEI	1.5 MURR	N/A	EO	HHL
FA-18	E-3	A	5 MURR/8 DEI	1.5 MURR	N/A	EO	HHL
FA-19	E-3	A	5 MURR/8 DEI	1.5 MURR	N/A	LF	LNN
FA-20	E-3	A	5 MURR/8 DEI	1% of 1.5 MURR	N/A	LF	LNN
FA-21	E-3	A	5 MURR/8 DEI	1.5 MURR	N/A	NO	LNN
FA-22	E-4	A	5 MURR/8 DEI	1.0 MURR	>2000R/hr	High Radiation	HLN
FA-23	E-4	A	5 MURR/8 DEI	1.0 MURR	>2000R/hr	High Radiation	HLN
FA-24	E-4	A	5 MURR/8 DEI	0.5 MURR	>2000R/hr	High Radiation	HLN
FA-25	E-5	U	5 MURR/8 DEI	2.0 MURR	N/A	EO	HHL
FA-26	E-5	U	5 MURR/8 DEI	1.0 MURR	N/A	EO	HHL
FA-27	E-6	A	5 MURR/8 DEI	5 MURR	N/A	EO	HHL
				8 DEIONIZERS	N/A	DF	
FA-28	E-6	U	5 MURR/8 DEI	1 MURR	N/A	MS	MLN
				1% of 4 MURR	1.0E-03	BT	
FA-29	E-6	U	5 MURR/8 DEI	1 MURR	N/A	MS	MLN
				1% of 4 MURR	1.0E-03	BT	
FA-30	E-6	U	5 MURR/8 DEI	1% of 5 MURR	1.0E-03	BT	LNN
FA-31	E-6	EU	5 MURR/8 DEI	5 MURR	N/A	EO	HHL
FA-32	E-6	BEU	5 MURR/8 DEI	5 MURR	N/A	EO	HHL
				4 DEIONIZERS	N/A	DF	
FA-33	E-7	U	5 MURR/8 DEI	1 MURR	N/A	MS	MLN
				1 % of 4 MURR	1.0E-03	BT	
				8 DEIONIZERS	1.0E-03	DF	
FA-34	E-7	U	5 MURR/8 DEI	5 MURR	N/A	EO	HHL
				8 DEIONIZERS	N/A	DF	
FA-35	E-7	EU	5 MURR/8 DEI	1 MURR	N/A	MS	HMN
				1% of 4 MURR	1.0E-03	BT	
				8 DEIONIZERS	1.0E-02	DF	
FA-36	E-7	A	5 MURR/8 DEI	1 MURR	N/A	MS	HMN
				1% of 4 MURR	1.0E-03	BT	
				8 DEIONIZERS	1.0E-02	DF	
FA-37	E-7	EU	5 MURR/8 DEI	4 MURR	N/A	EO	HHL
FA-38	E-7	U	5 MURR/8 DEI	4 MURR	estimated contamination dose		LNN

Table E-3, Event Consequences Derivation Data Summary (continued)

Crane Aisle Control Room							
CC-3	E-4	A	None	None	est.25Rem/hr	High Radiation	MNN
CC-4	E-4	U	None	None	est. 5 Rem	High Radiation	LNN
No Other Radiological Consequences							
Furnace Control Station							
No Radiological Consequences							
Receiving Area Transfer Bay							
TB-1	E-1	A	1 MURR	1 MURR	N/A	EO	HHN
TB-2	E-2	U	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-3	E-3	U	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-4	E-3	A	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-5	E-3	U	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-6	E-3	A	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-7	E-4	A	1 MURR	1 MURR	>2000R/hr	High Radiation	HLN
TB-8	E-6	A	1 MURR	1 MURR	N/A	EO	HHN
TB-9	E-6	U	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-10	E-6	EU	1 MURR	1 MURR	N/A	EO	HHN
TB-11	E-6	BEU	1 MURR	1 MURR	N/A	EO	HHN
TB-12	E-7	U	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-13	E-7	U	1 MURR	1 MURR	N/A	EO	HHN
TB-14	E-7	EU	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-15	E-7	A	1 MURR	1% of 1 MURR	1.0E-03	BT	LNN
TB-16	E-7	EU	1 MURR	1 MURR	N/A	EO	HHN
Dry Cave Area							
DC-1	E-1	A	7 MURR	7 MURR	N/A	EO	HHL
DC-2	E-2	U	7 MURR	1% of 7 MURR	1.0E-03	BT	LNN
DC-3	E-3	A	7 MURR	1% of 4 MURR	1.0E-03	BT	LNN
DC-4	E-3	U	7 MURR	1% of 4 MURR	1.0E-03	BT	LNN
DC-5	E-3	A	7 MURR	1% of 4 MURR	1.0E-03	BT	LNN
DC-6	E-4	A	7 MURR	1 MURR	>2000 R/hr	High radiation	HLN
DC-7	E-5	U	7 MURR	7 MURR	N/A	EO	HHL
DC-8	E-6	A	7 MURR	7 MURR	N/A	EO	HHL
DC-9	E-6	U	7 MURR	1% of 7 MURR	1.0E-03	BT	LNN
DC-10	E-6	EU	7 MURR	7 MURR	N/A	EO	HHL
DC-11	E-6	BEU	7 MURR	7 MURR	N/A	EO	HHL
DC-12	E-7	U	7 MURR	1% of 7 MURR	1.0E-03	BT	LNN
DC-13	E-7	U	7 MURR	7 MURR	N/A	EO	HHL
DC-14	E-7	EU	7 MURR	1% of 7 MURR	1.0E-03	BT	LNN
DC-15	E-7	A	7 MURR	1% of 7 MURR	1.0E-03	BT	LNN
DC-16	E-7	EU	7 MURR	4 MURR	N/A	EO	HHL
DC-17	E-7	U	7 MURR	7 MURR	estimated contamination dose		LNN

Table E-3, Event Consequences Derivation Data Summary (continued)

Transportation							
TR-1	E-1	U	4 MURR	4 MURR	N/A	EO	HHL
TR-2	E-2	U	4 MURR	1% of 4 MURR	1.0E-03	BT	LNN
TR-3	E-3	U	4 MURR	1% of 4 MURR	1.0E-03	BT	LNN
TR-4	E-3	A	4 MURR	1% of 4 MURR	1.0E-03	BT	LNN
TR-5	E-4	A	4 MURR	4 MURR	>2000 R/hr	High Radiation	HLN
TR-6	E-6	U	4 MURR	1% of 4 MURR	1.0E-03	BT	LNN
TR-7	E-6	U	4 MURR	4 MURR	N/A	EO	HHL
TR-8	E-6	EU	4 MURR	4 MURR	N/A	EO	HHL
TR-9	E-6	BEU	4 MURR	4 MURR	N/A	EO	HHL
TR-10	E-7	U	4 MURR	1% of 4 MURR	1.0E-03	BT	LNN
TR-11	E-7	EU	4 MURR	1% of 4 MURR	1.0E-03	BT	LNN
TR-12	E-7	A	4 MURR	1% of 4 MURR	1.0E-03	BT	LNN
TR-13	E-7	EU	4 MURR	4 MURR	N/A	EO	HHL

Mitigated Event Consequence Derivation

General

A preliminary accident analysis was performed for the LEF to determine the limiting radioactive nuclide inventory in a Missouri University Research Reactor (MURR) fuel assembly and the source terms for a set of generic accidents (Ref. 58). Also, the HA was performed to identify all possible accident events that can potentially occur at the LEF and the associated transport and storage facilities. A total of 113 potential hazardous events were identified.

The LEF accident analysis (Ref. 50) was performed to develop a limited set of accidents logically grouped to envelope all the events (excluding direct radiological exposures) identified in the HA. The accident analysis used the limiting nuclide inventory (MAR) of a MURR fuel assembly to determine the limiting source terms. The source terms were then used in the Consequence Analysis (Ref. 51) for the assessment of onsite and offsite radiological consequences. Per the hazard analysis methodology (Ref. 8), the results of the consequence analysis were used to determine the mitigated consequences for the HA and are summarized in table E-4 below. Direct radiological exposure events were evaluated using the expected dose rates from Reference 54. Tables E-4 and E-5 summarize the enveloping consequences used to develop the MHA.

Table E-4, Enveloping Accidents and Consequences for the LEF

Postulated Event	Onsite OEP at 100 m TDE (rem)	MOP TEDE (rem)	MOP Location (meters)	MOI[1] TEDE (rem)	MOI[2] TEDE (rem)
Crucible Failure Explosion – Plume 1	1.0E+01	1.0E+01	100	5.9E-02	
Crucible Failure Explosion – Plume 2	5.3E-02	5.3E-02	100	8.3E-05	
Crucible Failure Explosion – Total	1.0E+01	1.0E+01		5.9E-02	
Rapid Steam Generation – Plume 1	5.6E-04	7.8E-02	350	1.3E-02	
Rapid Steam Generation – Plume 2	3.1E-06	6.3E-04	350	1.1E-04	
Rapid Steam Generation – Total (RSG)	5.7E-04	7.9E-02		1.3E-02	
Furnace Extreme Overheating Transient – Plume 1	7.2E-03	1.7E+00	350	3.2E-01	
Furnace Extreme Overheating Transient – Plume 2	3.0E-06	6.0E-04	450	1.1E-04	
Furnace Extreme Overheating Transient – Total (FOT)	7.2E-03	1.7E+00		3.2E-01	

Table E-4, Enveloping Accidents and Consequences for the LEF (continued)

Postulated Event	Onsite OEP at 100 m TDE (rem)	MOP TEDE (rem)	MOP Location (meters)	MOI[1] TEDE (rem)	MOI[2] TEDE (rem)
Fire During Transport – Plume 1	5.2E+00	5.2E+00	100	1.6E-02	1.7E-02
Fire During Transport – Plume 2	2.2E+00	2.2E+00	100	3.3E-03	3.3E-03
Fire During Transport – Total (DTF)	7.3E+00	7.3E+00		1.9E-02	2.0E-02
Furnace Area Fire – Plume 1	2.0E+01	2.0E+01	100	1.5E-01	1.6E-01
Furnace Area Fire – Plume 2	7.0E+00	7.0E+00	100		
Furnace Area Fire – Plume 3	3.5E-01	3.5E-01	100	6.2E-04	6.2E-04
Furnace Area Fire – Total (FAF)	2.7E+01	2.7E+01		1.5E-01	1.6E-01
Storage Area Fire – Plume 1	8.1E+00	8.1E+00	100	3.0E-02	3.0E-02
Storage Area Fire – Plume 2	3.5E-01	3.5E-01	100	5.9E-04	5.9E-04
Storage Area Fire – Total (SAF)	8.5E+00	8.5E+00		3.0E-02	3.0E-02
Full Facility Fire – Plume 1	2.0E+01	2.0E+01	100	2.0E-01	
Full Facility Fire – Plume 2	1.1E+01	1.1E+01	100		
Full Facility Fire – Plume 3	7.6E-01	7.6E-01	100	1.1E-03	
Full Facility Fire – Total (FFF)	3.2E+01	3.2E+01		2.0E-01	
Aircraft (helicopter) Crash (ARC)[3]	<5.0			<0.5	
High Wind (HWE)[3]	<5			<0.5	
Tornado (TOR)[3]	<5			<0.5	
Earthquake (EQE)[3]	<5			<0.5	

1. Release durations based source term analysis (Yeung, 2000, Ref. 50).
2. Plume 1 release duration assumed to be 20 minutes (Ref. 51) and Plume 2 release duration is the same as that given in the source term analysis (Yeung, 2000, Ref. 50).
3. Consequences are determined by engineering judgement.

Table E-5, Consequences from Direct Radiation Exposure

Postulated Event	Distance	Dose Rate
Direct Radiation Exposure CR Viewing Window (DRE1)	1.0 foot from the aisle side surface of the viewing window	35.0 millirem/hour
Direct Radiation Exposure Cask/Canister (DRE2)	Surface of the cask or container	3.0 millirem/hour

Event Consequence Derivation Data Summary

Table E-6, provides a summary of the values used to arrive at the mitigated consequences for each event identified to exceed the evaluation guidelines for the onsite receptors in the unmitigated analysis. Values in the table include Event Number, Event Category, Frequency, Reference Accident, Dose from the Reference Accident to the onsite receptor at 100 meter and the MOI, and the HA mitigated consequences. The Consequence column lists the resulting consequences for the event: High (H), Moderate (M), Low (L), or Negligible (N) for the three receptor points Onsite 1, Onsite 2, and Offsite. SSCs and Administrative Controls assumed to mitigate the consequences are identified in Appendix D. Underlining in the Appendix D tables identifies the mitigating features of the LEF.

Table E-6, Event Mitigated Consequences Derivation Summary

Event	Category	Event Frequency	Reference Accident	Dose at 100 Meters (Rem)	Offsite Dose (MOI) (Rem)	Consequence (On1, On2, Offsite)
Furnace Area						
FA-1	E-1	EU	FAF	27	0.160	MMN
FA-2	E-1	U	FAF	<25 [1]	<0.160 [1]	LLN
FA-2A	E-1	EU	FFF	32	0.200	MMN
FA-4	E-2	BEU	RSG	0.079 [2]	0.013	NNN
FA-5	E-2	BEU	RSG	0.079 [2]	0.013	NNN
FA-11	E-3	EU	FOT	1.7 [2]	0.320	NNN
FA-13	E-3	U	FOT	1.7 [2]	0.320	LNN [3]
FA-14	E-3	U	FOT	1.7 [2]	0.320	LNN [3]
FA-15	E-3	EU	FOT	1.7 [2]	0.320	NNN
FA-17	E-3	BEU	FOT	1.7 [2]	0.320	NNN
FA-18	E-3	BEU	FOT	1.7 [2]	0.320	NNN
FA-22	E-4	U	DRE1	> 35 mR/hr	-	LNN
FA-23	E-4	U	DRE2	>3mR/hr	-	LNN
FA-24	E-4	U	DRE1	> 35 mR/hr	-	LNN
FA-25	E-5	BEU	CRI	-	-	NNN
FA-26	E-5	BEU	CRI	-	-	NNN
FA-27	E-6	EU	FFF	32	0.200	MMN
FA-28	E-6	EU	FAF	<25 [1]	<0.160 [1]	LLN
FA-29	E-6	EU	FAF	<25 [1]	<0.160 [1]	LLN
FA-31	E-6	BEU	ARC	<5	<0.5	NNN
FA-33	E-7	BEU	EQE	<5	<0.5	NNN
FA-34	E-7	EU	FFF	32	0.030	MMN
FA-35	E-7	BEU	TOR	<5	<0.5	NNN
FA-36	E-7	BEU	HWE	<5	<0.5	NNN
FA-37	E-7	EU	FFF	32	0.030	MMN
Crane Aisle Control Room						
CC-3	E-4	U	DRE1	> 35 mR/hr	-	LNN
Furnace Control Station						
No events exceed the onsite guidelines						
Receiving Area Transfer Bay						
TB-1	E-1	U	FAF	<25 [1]	<0.160 [1]	LLN
TB-7	E-4	U	DRE1	>3mR/hr	-	LNN
TB-8	E-6	EU	FAF	<25 [4]	<0.160 [4]	LLN
TB-10	E-6	BEU	ARC	<5	<0.5	NNN
TB-13	E-7	EU	FAF	<25 [4]	<0.160 [4]	LLN
TB-16	E-7	EU	FAF	<25 [4]	<0.160 [4]	LLN

Table E-6, Event Mitigated Consequences Derivation Summary (continued)

Dry Cave Area						
DC-1	E-1	U	SAF	8.5	0.030	LLN
DC-6	E-4	U	DRE2	>3mR/hr	-	LNN
DC-7	E-5	BEU	CRI	-	-	NNN
DC-8	E-6	EU	SAF	8.5	0.030	LLN
DC-10	E-6	BEU	ARC	<5	<0.5	NNN
DC-13	E-7	EU	SAF	8.5	0.030	LLN
DC-16	E-7	EU	SAF	8.5	0.030	LLN
Transportation						
TR-1	E-1	EU	DTF	7.3	0.020	LLN
TR-5	E-4	U	DRE2	>3mR/hr	-	LNN
TR-7	E-6	EU	DTF	7.3	0.020	LLN
TR-8	E-6	BEU	DTF	7.3	0.020	LLN
TR-13	E-7	EU	DTF	7.3	0.020	LLN

Notes:

1. Does not include Process Water Deionizers
2. Maxmum onsite dose at 350 meters
3. No secondary confinement
4. Only includes 1 MURR