Attachment 2

Integrated Safety Analysis Summary
Blended Low-Enriched Uranium Preparation Facility, Revision 1 (21T-04-0049)

(Non-Proprietary Version)

(450 pages to follow)

NON-PROPRIETARY

21T-04-0049
HEA-13

Integrated Safety Analysis Summary

Blended Low-Enriched Uranium

Preparation Facility

Revision 1

February 6, 2004

UNCLASSIFIED

RP Drake 02/06/04
Authorized Classifier Date

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ACRONYMS AND ABBREVIATIONS

acfm	actual cubic feet per minute
ACGIH	American Conference of Government Industrial Hygenists
AEC	active engineered control
AEGL	Acute Exposure Guideline Level
AIChE	American Institute of Chemical Engineers
ALARA	as low as reasonably achievable
ARF	airborne release fraction
ARR	airborne release rate
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
BCSA	bulk chemical storage area
BLEU	blended low enriched uranium
BLEVE	boiling liquid expanding vapor explosion
BPF	BLEU Preparation Facility
BDC	baseline design criteria
BWXT	BWX Technologies, Inc.
CAAS	Criticality Accident Alarm System
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CM	configuration management
CPVC	chlorinated polyvinyl chloride
CRT	cargo restraint transporter
DCF	dose conversion factor
DI	deionized (water)
DOE	U.S. Department of Energy
DR	damage ratio
EMI	electromagnetic interference
ERPG	Emergency Response Planning Guidelines
FHA	Fire Hazards Analysis
FRP	fiberglass reinforced plastic

fpm	feet per minute
gpm	gallons per minute
HEPA	high efficiency particulate air (filter)
HE	high enriched
HEU	high-enriched uranium
HF	hydrogen fluoride
HNO_3	nitric acid
hr	hour
HSSA	High Security Storage Area
HVAC	heating, ventilation and air conditioning
ICRP	International Commission on Radiological Protection
IDLH	immediately dangerous to life or health
IPF	Industrial Park Facility
IROFS	items relied on for safety
ISA	integrated safety analysis
kg	kilogram
kVA	kilovolt ampere
kW	kilowatt
LC_{50}	concentration that is fatal to 50% of those exposed
LCO	limiting condition for operation
LEL	lower explosive limit
LEU	low-enriched uranium
LFL	lower flammable limit
LLW	low-level (radioactive) waste
LPF	leak path factor
LPG	liquefied propane gas
MAA	Material Access Area
MAR	material at risk
MC&A	material control and accountability
MCC	motor control center
MFA	manual fire alarm

mrem	millirem
N	natural
NCS	nuclear criticality safety
NCSE	nuclear criticality safety evaluation
NEC/IEEE	National Electric Code/Institute of Electrical Engineers and Electricians
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NFS	Nuclear Fuel Services, Inc.
NIOSH	National Institute for Occupational Safety and Health
NO_x	nitrogen oxides
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NSA	NuclearSafety Associates
NU	natural uranium
OSHA	Occupational Safety and Health Administration
PEVS	process exhaust ventilation system
PHA	process hazards analysis
P&ID	piping and instrumentation diagram
PLC	programmable logic controller
POG	process off-gas
POTW	publicly owned treatment works
PRA	probabilistic risk assessment
psig	pounds per square inch, gauge
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RARF	respirable airborne release fraction
R&D	research and development
REAC/TS	Radiation Emergency Assistance Center/Training Site
RF	respirable fraction
RWP	radiological work permit

SBC	Standard Building Code
SCAPA	Subcommittee on Consequence Assessment and Protection Actions
SNM	special nuclear material
SRP	standard review plan
SRS	Savannah River Site
SST	safe secure transport
SX	solvent extraction
TEDE	total effective dose equivalent
TEELs	Temporary Emergency Exposure Levels
UAl	uranium aluminum alloy
UEL	upper explosive limit
UFG	unfavorable geometry
UFL	upper flammable limit
UM	uranium metal
UN	uranyl nitrate
UNB	Uranyl Nitrate Building
UPS	uninterruptible power supply
U	uranium
UVCE	unconfined vapor cloud explosion
VAC	volts alternating current
WOG	wet off-gas
WWTF	Waste Water Treatment Facility

DEFINITIONS

Absorbed dose means the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

Active engineered control (AEC) means a device that uses active sensors, electrical components, or moving parts to maintain safe process conditions without any required human action.

Acute means a single radiation dose or chemical exposure event or multiple radiation dose or chemical exposure events occurring within a short time (24 hours or less).

Airborne Release Rate (ARR) means the fraction of the total available material being suspended in air available for transport from a continuous mechanism. The ARR is expressed as the fraction of the total available material being suspended per unit time.

Airborne Release Fraction (ARF) means the fraction of impacted material that becomes suspended in air available for transport following a specific set of physical stresses.

Available and reliable to perform their function when needed means that, based on the analyzed, credible conditions in the integrated safety analysis, items relied on for safety will perform their intended safety function when needed, and management measures will be implemented that ensure compliance with the performance requirements of 10 CFR 70.61, considering factors such as necessary maintenance, operating limits, common-cause failures, and the likelihood and consequences of failure or degradation of the items and measures.

Baseline Design Natural Phenomena Event is a physically credible natural phenomena event not expected to occur during plant lifetime that has the capability to exceed the performance criteria specified in 10 CFR 70.61. Protection is afforded by designing and constructing a facility to applicable sections of the Standard Building Code and by ensuring operational adherence to this code through a configuration management change control process. Adherence to 10 CFR 70.62(c)(iv) and 10 CFR 70.64 (a)(2) is demonstrated by eliminating potential high or intermediate consequences through baseline design thresholds applied to establish a defined protection envelope for each type of natural phenomena event.

Committed dose equivalent ($H_{T,50}$) means the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed effective dose equivalent ($H_{E,50}$) is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues $\left(H_{E,50} = \sum W_T H_{T,50}\right)$.

Configuration management (CM) means a management measure that provides oversight and control of design information, safety information, and records of modifications (both temporary

and permanent) that might impact the ability of items relied on for safety to perform their functions when needed.

Controlled area means an area outside of a restricted area but inside the site boundary, access to which can be limited by the Licensee for any reason (10 CFR 20.1003). For determination of off-site dose consequences, the controlled area boundary is the security controlled double fence line, which is referred to as the protected area at NFS.

Critical mass of special nuclear material means special nuclear material in a quantity exceeding 700 grams of contained uranium-235; 520 grams of uranium-233; 450 grams of plutonium; 1500 grams of contained uranium-235, if no uranium enriched to more than 4 percent by weight of uranium-235 is present; 450 grams of any combination thereof; or one-half such quantities if massive moderators or reflectors made of graphite, heavy water, or beryllium are present.

Deep-dose equivalent (H_d), which applies to external whole-body exposure, is the dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2).

Dose equivalent (H_T) means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv).

Double contingency principle means that designs for processes involving special nuclear material should incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.

Effective kilograms of special nuclear material means: (1) For plutonium and uranium-233 their weight in kilograms; (2) For uranium with an enrichment in the isotope U-235 of 0.01 (1%) and above, its element weight in kilograms multiplied by the square of its enrichment expressed as a decimal weight fraction; and (3) For uranium with an enrichment in the isotope U-235 below 0.01 (1%), its element weight in kilograms multiplied by 0.0001.

Hazard means a physical or chemical characteristic of a material, system, process, or facility that has the potential for causing harm.

Hazardous chemicals produced from licensed materials means substances having licensed material as precursor compound(s) or substances that physically or chemically interact with licensed materials; and that are toxic, explosive, flammable, corrosive, or reactive to the extent that they can endanger life or health if not adequately controlled. These include substances commingled with licensed material, and include substances such as hydrogen fluoride that is produced by the reaction of uranium hexafluoride and water, but do not include substances prior to process addition to licensed material or after process separation from licensed material.

Integrated safety analysis (ISA) means a systematic analysis to identify process, facility and external hazards and their potential for initiating accident sequences, the potential accident sequences, their likelihood and consequences, and the items relied on for safety. As used here,

integrated means joint consideration of safety measures and controls that might otherwise conflict, including integration of radiation safety, nuclear criticality safety, fire protection, and chemical safety. However, with respect to compliance with the regulations, the NRC requirement is limited to consideration of the effects of all relevant hazards on radiological safety, nuclear criticality safety, and chemical hazards directly associated with handling NRC licensed radioactive material. An ISA can be performed process by process, but all processes must be integrated, and process interactions considered.

Integrated safety analysis summary means a document or documents submitted with a license application, license amendment application, license renewal application, or pursuant to 10 CFR 70.62(c)(3)(ii) that provides a synopsis of the results of the integrated safety analysis and contains the information specified in 10 CFR 70.65(b).

Items relied on for safety (IROFS) mean structures, systems, equipment, components, and activities of personnel that are relied on to prevent potential accidents at a facility that could exceed the performance requirements in 10 CFR 70.61 or to mitigate their potential consequences. This does not limit the licensee from identifying additional structures, systems, equipment, components, or activities of personnel (i.e., beyond those in the minimum set necessary for compliance with the performance requirements) as items relied on for safety.

Management measures mean the functions performed by the licensee, generally on a continuing basis, that are applied to items relied on for safety, to ensure the items are available and reliable to perform their functions when needed. Management measures include configuration management, maintenance, training and qualifications, procedures, audits and assessments, incident investigations, records management, and other quality assurance elements.

Material at Risk (MAR) means the amount of hazardous material available to be acted on by a given physical stress.

Passive engineered control means a device that uses only fixed physical design features to maintain safe process conditions without any required human action.

Respirable Fraction (RF) means the fraction of the ARF or ARR that is actually respirable, all vapors, or any particulate material that has a diameter of less than 10 μm (3.9×10^{-5} in.).

Site boundary means that line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Special nuclear material (SNM) means (1) plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of Section 51 of the act, determines to be special nuclear material, but does not include source material; or (2) any material artificially enriched by any of the foregoing but does not include source material;

Total Effective Dose Equivalent (TEDE) means the sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Unrestricted area means an area, access to which is neither limited nor controlled by the licensee.

Worker, when used in Subpart H of 10 CFR 70, means an individual who receives an occupational dose as defined in 10 CFR 20.1003.

INTRODUCTION AND SUMMARY

This revision to the Integrated Safety Analysis (ISA) Summary (Revision 1) was prepared by Nuclear Fuel Services, Inc. (NFS) for the Blended Low Enriched Uranium (BLEU) Preparation Facility (BPF). This revision includes updates to the process descriptions and corresponding consequence analysis, risk assessment, and items relied on for safety (IROFS) list, along with updates to the chemical standards (Section 7) based on the Subcommittee on Consequence Assessment and Protection Actions (SCAPA) database. NFS responses to NRC requests for additional information have also been included.

The BPF is constructed mainly within Building [redacted] in the protected area of the NFS Site. The BPF is licensed under 10 CFR Part 70, enacted on September 29, 2000. Processes within the BPF convert High Enriched Uranium (HEU) materials to High Enriched (HE) uranyl nitrate solution and then combine the HE uranyl nitrate solution with Natural (N) uranyl nitrate solution to make a Low Enriched (LE) uranyl nitrate product. Blending of natural uranium and high-enriched uranium is licensed on the NFS Site as part of the [redacted] Complex (Section 15.3.13 of License SNM-124). The [redacted] Complex has been decommissioned, and therefore, the HEU to LEU blending operation has been moved to Building [redacted] According to 10 CFR Part 70, an Integrated Safety Analysis (ISA) is to be conducted on currently operating and new facilities to assure that the performance criteria delineated in 10 CFR 70.61 are met. This ISA Summary is a synopsis of the results of the ISA performed on the BPF design. This ISA Summary was prepared based on the guidance provided in NUREG-1513 "Integrated Safety Analysis Guidance Document" and NUREG-1520, "Standard Review Plan".

As defined in 10 CFR Part 70, an ISA is a systematic analysis to identify facility and external hazards, potential accident sequences, their likelihood and consequences, and the items relied on for safety. The analysis includes joint consideration of all relevant hazards, including radiological, nuclear criticality, fire, and chemical. The ISA is limited to the effects of all relevant hazards on radiological safety, nuclear criticality safety, or chemical hazards directly associated with handling NRC licensed radioactive material. NFS has performed an ISA, and prepared this ISA Summary, to meet the above requirements. The key elements and sequential steps involved in development of the ISA Summary are shown in Figure 5-1. This process is defined in detail in Section 5 of this ISA Summary.

The information provided in the BPF ISA Summary is organized to follow the content requirements specified in 10 CFR 70.65.b: Site description, Facility description, Process description, Compliance with 70.61 requirements, ISA Team qualifications and ISA methods, List of IROFS, Quantitative standards, Sole IROFS, and Definitions of Unlikely, Highly Unlikely and Credible. As demonstrated in Sections 4.2 and 4.3, all credible accident sequences for the BPF that result in high or intermediate consequences to the worker, public, or environment, have been shown to be highly unlikely or unlikely based on the credited IROFS listed in Section 6. The management measures defined in Section 4.4 are considered the minimum necessary to ensure that the credited IROFS are available and reliable to perform their required safety function if needed. Based on these results, this ISA Summary demonstrates compliance with 10 CFR 70 requirements, and applicable regulatory guidance.

1.0 SITE DESCRIPTION

1.1 GEOGRAPHY

The NFS Erwin Site is located approximately in the center of Unicoi County in the northeastern portion of the State of Tennessee (Figure 1-1). Figures 1-2 and 1-3 identify structures near the site within a 1-mile radius of the NFS Site. The site is in the Banner Hill community within the Town of Erwin limits, approximately 50 miles north-northeast of Asheville, North Carolina and approximately 20 miles south of Johnson City, Tennessee. It is located 800 to 1000 feet from the southeastern bank of the Nolichucky River, is bounded by Carolina Avenue to the east, a CSX Transportation railroad yard to the west, Martin Creek to the north and the Studsvik Processing Facility to the south. The site occupies approximately 70 acres of land in a southwest-to-northeast oriented valley, bounded on both sides by the Blue Ridge Mountains of the Appalachian Mountain chain. The site elevation ranges from approximately 1,638 to 1,680 feet above sea level, and the surrounding mountains have a maximum elevation of about 2,480 feet above sea level.

The NFS Site boundary diagram, Figure 1-4, shows that the Controlled Area portion of the site includes the main office, storage, waste handling, and production areas. The Controlled Area is surrounded by a double fence line and perimeter intrusion detection and assessment system, patrolled by armed guards, and access controlled. The NFS Site boundary as shown on Figure 1-4 is approximately 518 feet from the main stack and approximately 120 feet from the BPF at the closest off-site location. The closest residence is approximately 650 feet from the BPF (NFS Emergency Plan).

1.2 DEMOGRAPHY

The plant is near the southwest boundary of the Town of Erwin, which has a population of 5,610 according to the 2000 U.S. Census. Unicoi County has a population of 17,713 (2001 U.S. Census). The breakdown of population within a 1-mile radius of the site is not available; however, it is estimated to be approximately 2,800 people (NFS Emergency Plan). The nearest residence is approximately 500 feet east of the Controlled Area. A 1-mile radius would include portions of the residential neighborhoods of Banner Hill, Love Station, and Evergreen. The following public and industrial facilities with anticipated occupancies greater than 10, are located within a 1-mile radius of the site:

Figure 1-1
NFS General Site Area

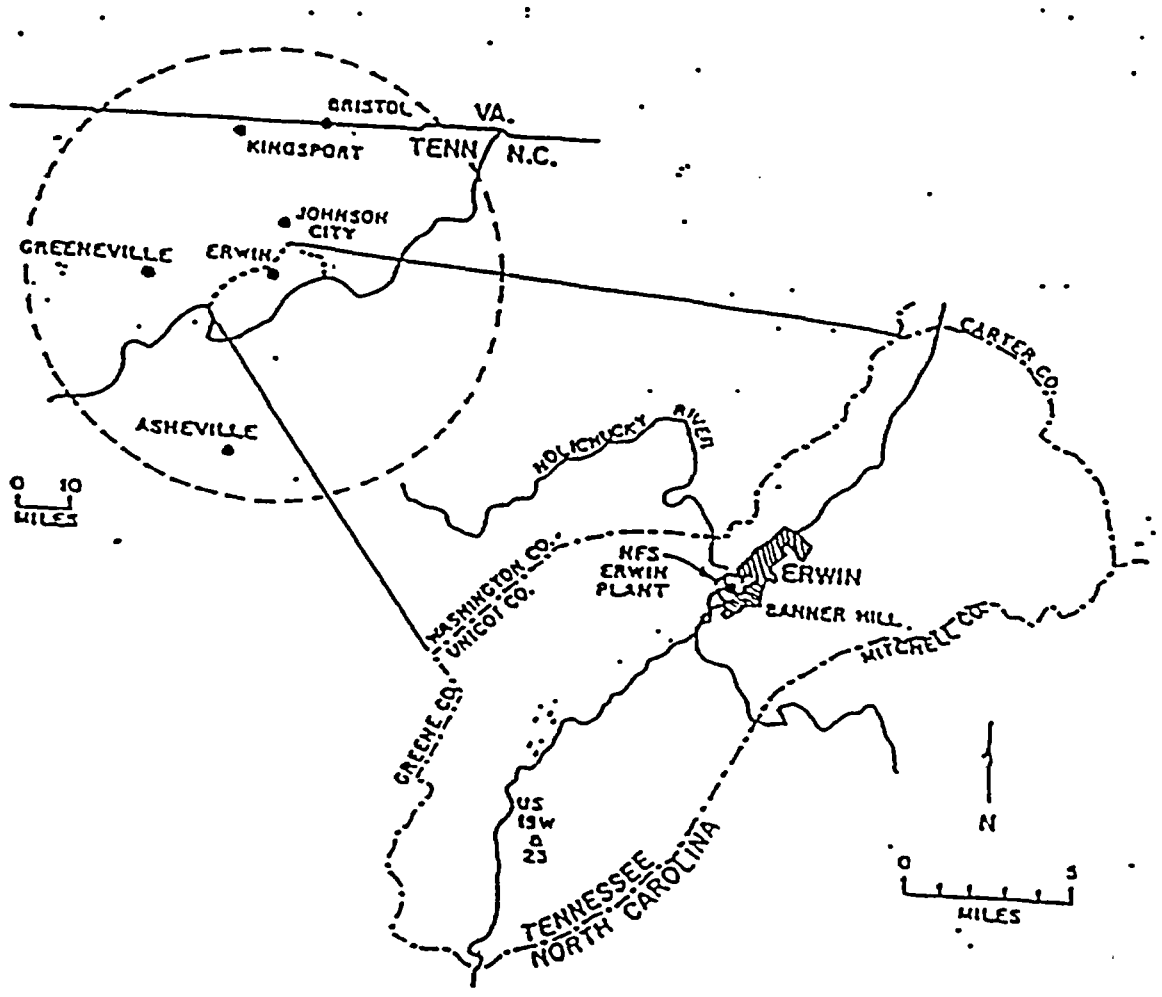
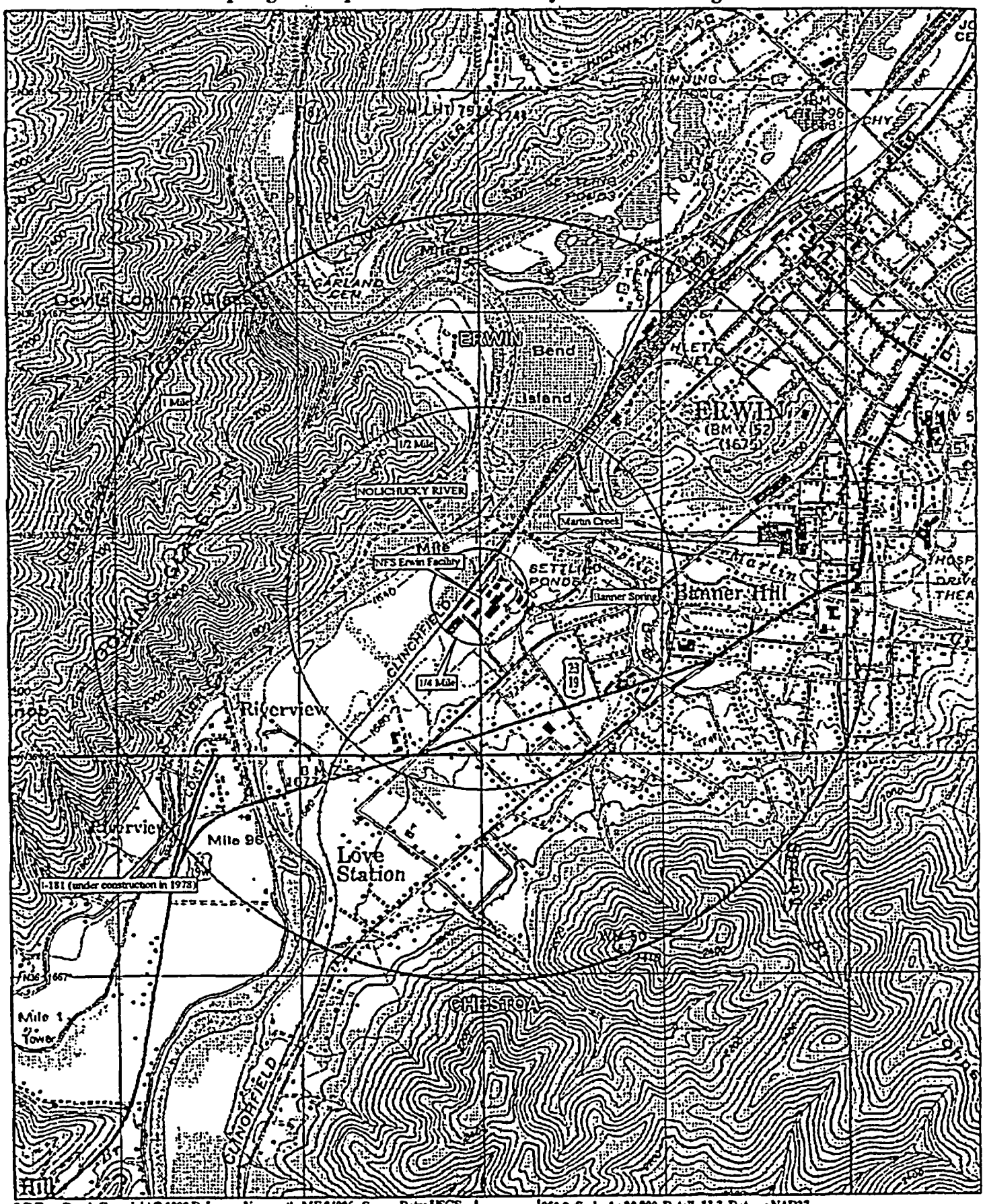


Figure 1-2

Topological Map of NFS Erwin Facility and Surrounding Area



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS 850 ft Scale: 1 : 20,800 Detail: 13-3 Datum: NAD27

Figure 1-3

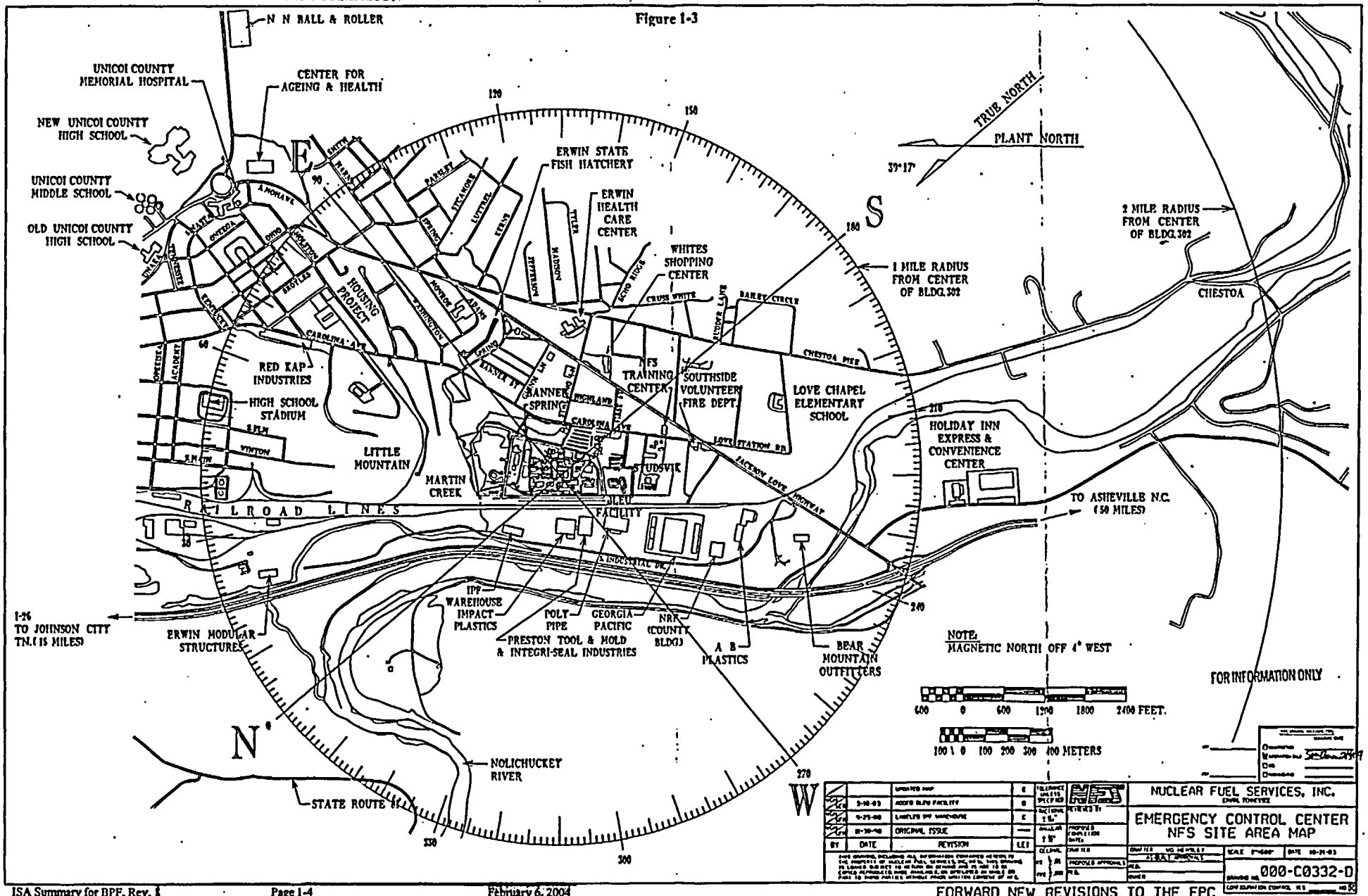
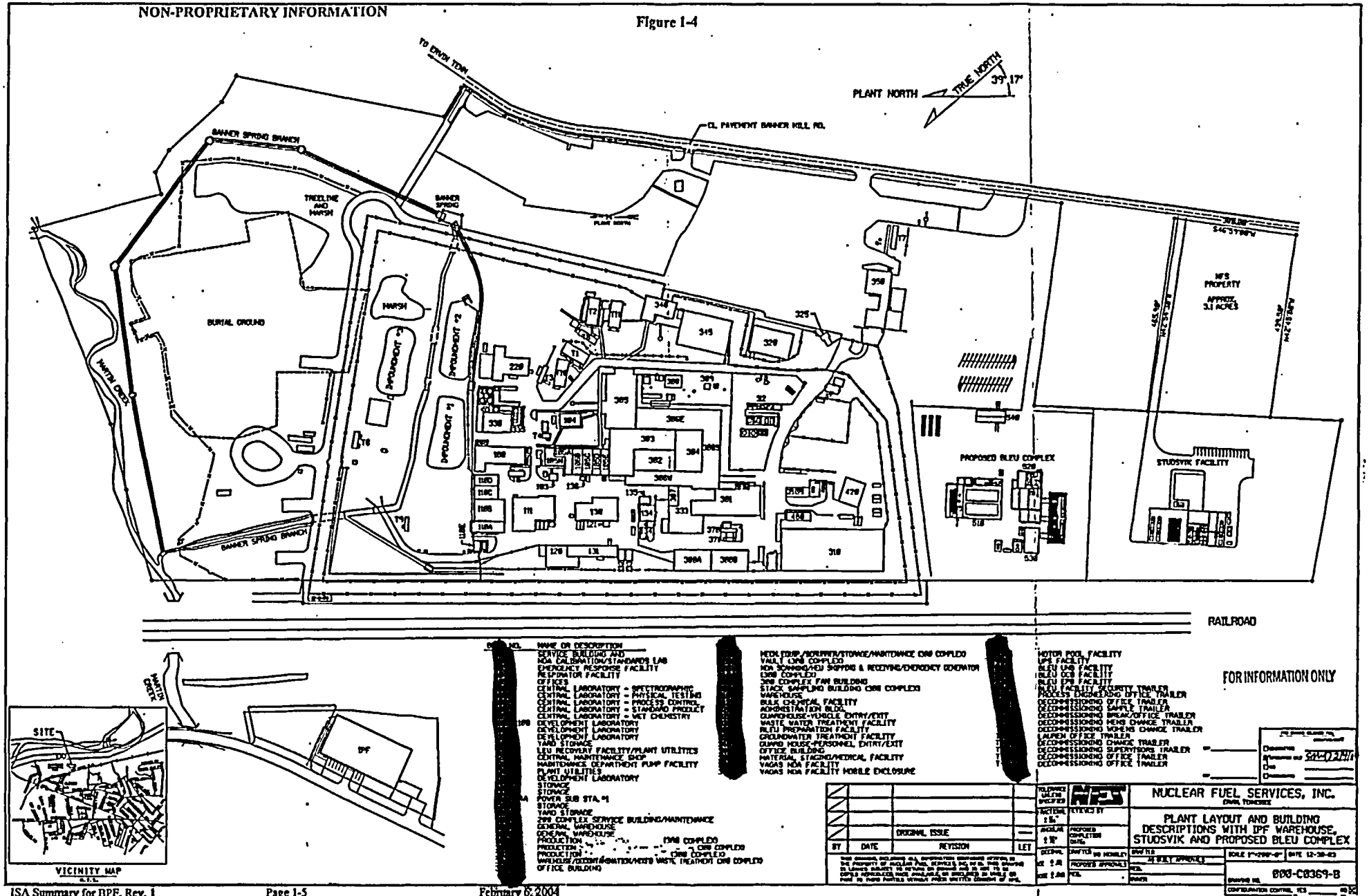

N N BALL & ROLLER
UNICOI COUNTY MEMORIAL HOSPITAL
CENTER FOR AGEING & HEALTH
NEW UNICOI COUNTY HIGH SCHOOL
UNICOI COUNTY MIDDLE SCHOOL
OLD UNICOI COUNTY HIGH SCHOOL
ERWIN STATE FISH HATCHERY
ERWIN HEALTH CARE CENTER
WHITES SHOPPING CENTER
TRUE NORTH
PLANT NORTH
39°17'
2 MILE RADIUS FROM CENTER OF BLDG.302
1 MILE RADIUS FROM CENTER OF BLDG.302
CHESTOA
HOUSING PROJECT
RED KAP INDUSTRIES
HIGH SCHOOL STADIUM
LITTLE MOUNTAIN
MARTIN CREEK
BANNER SPRING
NFS TRAINING CENTER
SOUTHSIDE VOLUNTEER FIRE DEPT.
LOVE CHAPEL ELEMENTARY SCHOOL
HOLIDAY INN EXPRESS & CONVENIENCE CENTER
TO ASHEVILLE N.C. (50 MILES)
RAILROAD LINES
STUDSVIK
BLEU FACILITY
IPP WAREHOUSE IMPACT PLASTICS
POLY-PIPE
GEORGIA PACIFIC
NRR (COUNTY BLDG)
PRESTON TOOL & MOLD & INTEGRI-SEAL INDUSTRIES
A & B PLASTICS
BEAR MOUNTAIN OUTFITTERS
ERWIN MODULAR STRUCTURES
I-26 TO JOHNSON CITY TN.(15 MILES)
NOLICHUCKEY RIVER
STATE ROUTE 81
NOTE: MAGNETIC NORTH OFF 4° WEST
FOR INFORMATION ONLY
600 0 600 1200 1800 2400 FEET.
100 0 100 200 300 400 METERS
NUCLEAR FUEL SERVICES, INC.
EMERGENCY CONTROL CENTER
NFS SITE AREA MAP
000-C0332-D

Figure 1-4


TO ERWIN TOWN
PLANT NORTH
TRUE NORTH
39° 17'
CL PAVEMENT BANNER HILL RD.
BANNER SPRING BRANCH
TREELINE AND MARSH
BANNER SPRING
BURIAL GROUND
MARTIN CREEK
MARSH
IMPOUNDMENT #3
IMPOUNDMENT #2
IMPOUNDMENT #1
BANNER SPRING BRANCH
PROPOSED BLEU COMPLEX
STUDSVIK FACILITY
NFS PROPERTY
APPROX. 3.1 ACRES
RAILROAD
SITE
IPF
VICINITY MAP
BLDG. NO. NAME OR DESCRIPTION
SERVICE BUILDING AND
NDA CALIBRATION/STANDARDS LAB
EMERGENCY RESPONSE FACILITY
RESPIRATOR FACILITY
OFFICES
CENTRAL LABORATORY - SPECTROGRAPHIC
CENTRAL LABORATORY - PHYSICAL TESTING
CENTRAL LABORATORY - PROCESS CONTROL
CENTRAL LABORATORY - STANDARD PRODUCT
CENTRAL LABORATORY - WET CHEMISTRY
DEVELOPMENT LABORATORY
DEVELOPMENT LABORATORY
DEVELOPMENT LABORATORY
YARD STORAGE
LEU RECOVERY FACILITY/PLANT UTILITIES
CENTRAL MAINTENANCE SHOP
MAINTENANCE DEPARTMENT PUMP FACILITY
PLANT UTILITIES
DEVELOPMENT LABORATORY
STORAGE
STORAGE
POWER SUB STA. #1
STORAGE
YARD STORAGE
IPF COMPLEX SERVICE BUILDING/MAINTENANCE
GENERAL WAREHOUSE
GENERAL WAREHOUSE
PRODUCTION
PRODUCTION
PRODUCTION
WAREHOUSE/DECONTAMINATION/HOT WASTE TREATMENT
OFFICE BUILDING
MOTOR POOL FACILITY
UPS FACILITY
BLEU UNB FACILITY
BLEU OCB FACILITY
BLEU EPB FACILITY
BLEU FACILITY SECURITY TRAILER
PROCESS ENGINEERING OFFICE TRAILER
DECOMMISSIONING OFFICE TRAILER
DECOMMISSIONING SAMPLE TRAILER
DECOMMISSIONING BREAK/OFFICE TRAILER
DECOMMISSIONING MENS CHANGE TRAILER
DECOMMISSIONING WOMENS CHANGE TRAILER
LAUREN OFFICE TRAILER
DECOMMISSIONING CHANGE TRAILER
DECOMMISSIONING SUPERVISORS TRAILER
DECOMMISSIONING OFFICE TRAILER
DECOMMISSIONING OFFICE TRAILER
FOR INFORMATION ONLY
ORIGINAL ISSUE
BY DATE REVISION LET
NUCLEAR FUEL SERVICES, INC.
PLANT LAYOUT AND BUILDING DESCRIPTIONS WITH IPF WAREHOUSE, STUDSVIK AND PROPOSED BLEU COMPLEX
000-C0369-B

Public or Industrial Facility	Anticipated Occupancy
NFS Industrial Park Facility (See Section 15.11 of Part II of NFS License SNM-124)	10
Preston Tool and Mold	10
Bear Mountain Outfitters	10
Integri-Seal Industries	13
CSX Transportation Railroad Yard	20
Erwin Modular Structures	20
CSR Poly Pipe, Inc.	35
Georgia Pacific	58
Studsvik Processing Facility	60
Impact Plastics, Inc.	80
AB Plastics	150
White's Plaza	200
Erwin Health Care Center	200
Love Chapel Elementary School	250
Gentry Stadium	2,500

1.2.1 Public Facility Impacts

1.2.1.1 Studsvik Processing Facility

The Studsvik Processing Facility (SPF), owned by Studsvik, LLC, is a State of Tennessee licensed low level radioactive waste processing facility located greater than 223 feet southwest of the Uranyl Nitrate Building (UNB) and further south of Building [redacted] The SPF processes low level contaminated ion exchange resins from secondary coolant operations at nuclear power plant facilities. The total average inventory of radioactivity during 2001 was approximately 900 curies with the following radionuclides providing significant contributions (>1%) to the inventory: Co^{58}, Co^{60}, Mn^{54}, Fe^{55}, Cs^{134}, Cs^{137}, and Ni^{63}.

A failure of engineering controls at Studsvik could potentially lead to a release of radiological materials to the air. However, because of its source term, the facility constitutes a low hazard facility, which State of Tennessee regulations exempt from having an Emergency Plan. In the event that a radiological release should occur, Studsvik would notify NFS of appropriate protective actions to take. Additional response measures may be taken by NFS, which may include the

activation of its Emergency Response Organization. The response would be initiated in accordance with the NFS Emergency Plan.

A Studsvik Bulk Chemical Storage Accident, would most likely be bounded by an NFS Bulk Chemical Storage Accident. Therefore, there are no bulk chemical accidents at the Studsvik facility that would result in an intermediate or high consequence event at the BPF.

Studsvik uses bulk NaOH inside the process facility building, and liquid nitrogen and liquid oxygen tanks located on the west side of their process building. In addition, a diesel fuel tank is located on the south east side of their process facility. Below are the tank sources, capacities, pressures and locations relative to the Studsvik process facility.

Liq. Nitrogen [redacted] @ 250 psi (Outside and West)
Liq. Oxygen [redacted] @ 250 psi (Outside and West)
NaOH [redacted] @ Atm. (Inside process building)
Diesel Fuel [redacted] @ Atm. (Outside and Southeast)

1.2.1.2 CSX Transportation Railroad Yard

The CSX Transportation (CSXT) railroad yard starts approximately one-half mile south of the NFS Site and extends several miles north into the main yard in downtown Erwin. The main line expands to 7 sets of tracks as it passes by NFS and eventually into approximately 30 lines at the main terminal in downtown Erwin. The function of the yard is mainly to provide for inspection, maintenance and repair of rail cars. None of the tracks pass straight through the yard, and the trains all stop for crew change or yard operations. The speed in the yard is controlled to less than 10 mph.

The closest track to the NFS Controlled Area is approximately 10 feet from the outer fence line of the Controlled Area. The inner fence line is approximately 20 feet from the outer fence line, resulting in a distance of 30 feet from the track to the controlled area of the NFS site. Due to the low speeds in the Erwin yard area and the extensive regulations involving transport of hazardous materials by rail, any derailments or other abnormal conditions that may occur in the yard area do not present a significant risk to NFS operations. The extensive railroad transportation requirements include detailed package integrity specifications, pressure relief requirements, inspection and acceptance requirements, handling and loading requirements, expedited movements (49 CFR Part 174.14), emergency response, hazardous materials employee training, and quality assurance (49 CFR Part 179.7).

The bounding external event from railroad operations would be a liquid propane gas (LPG) railcar boiling liquid expanding vapor explosion (BLEVE). A BLEVE creates a large rising fireball of very short duration, which presents a radiant heat

and burn injury exposure to people who may be outside and not in fire-rated protective clothing. A BLEVE does not produce remote overpressures and would not present a significant thermal exposure from a property damage standpoint.

LPG railcars have very strict design and operational requirements. In addition to the mechanical standards common to all freight cars, they must also meet the requirements of both 49 CFR Part 179 and the Association of American Railroads (AAR) Specifications for Tank Cars. Builders must seek design approval from the AAR Tank Car Committee before building a tank car. Repairs must be performed only by facilities certified by the AAR. Normally, the maximum LPG railcar inventory is 30,000 gallons (approximately 85% fill density).

Thermal insulation systems are installed to aid LPG tank cars in resisting the effects of fires in derailments. Heat shields are required to minimize damage to the tank car heads. Thermal protection, not to be confused with insulation, is installed on LPG tank cars to protect the tank from flame impingement. It is designed to keep tank metal temperatures below 800°F for 100 minutes (pool fire impingement) and 30 minutes from direct torch fire impingement.

Since the implementation of stricter design standards (required for new cars beginning in 1978 – retrofit of existing cars was completed in 1981), there have been no reports of major BLEVE or vapor explosion incidents involving these cars although a number of minor derailments have occurred.

The Federal Railroad Administration (FRA) recently reported continued improvements in overall railroad safety performance, and especially for CSXT operations in its latest industry report: Safety Assurance and Compliance Program Accomplishments for CY 2001. The FRA closely regulates the railroad industry, and maintains a detailed reporting and monitoring program to ensure that root causes of safety issues are addressed and resolved. However, as mentioned above, specific emergency response requirements from CSXT and from the NFS Emergency Plan would be initiated if any hazardous conditions occurred in the yard area adjacent to NFS.

In summary, based on the low speed of the trains in the yard, the distance to NFS facilities, strict rail hazardous transportation requirements, and the very low incident record in the Erwin yard near NFS, the CSXT railroad is not considered to be a significant concern for NFS operations.

1.2.1.3 Local and Regional Airports

The Tri-Cities Regional Airport is located approximately 40 miles north of NFS near the town of Gray, which is centrally located between the three major cities of Kingsport, Bristol, and Johnson City. The airport consists of an 8,000-foot long primary east-west runway and a 4,447-foot long secondary north-south runway. The flight patterns for airliners arriving and departing from the runways do not

cross over the NFS Site. Considering the relatively small size of the airport, and the significant distance from NFS, the air traffic from this airport does not represent a significant concern for the NFS Site.

Other local airports are operated in Johnson City and Elizabethton, however, these are small operations and are located at least 25 miles from NFS. The flight patterns to these airports are not a concern for site or BPF operations.

1.2.1.4 Carolina Avenue

Carolina Avenue runs parallel to the east property boundary of the NFS Site. There is only one access point to the site from Carolina Avenue. The vehicle traffic on Carolina Avenue has not been specifically evaluated, however, the road is approximately 300 feet from the site Controlled Area. Considering this distance, and the concrete barrier with security fencing installed next to the road, vehicles on Carolina Avenue would not be a significant concern for site operations.

1.3 METEOROLOGY

1.3.1 Climate

The climate in the vicinity is characterized by warm, humid summers and relatively mild winters. Cooler, drier weather in the area is usually associated with polar continental air masses, whereas warmer, wetter weather is generally associated with gulf maritime masses. The average annual temperature in 2000 was 55.1°F. The average daily minimum temperature was 23.8°F in January; and 83.4°F was the average daily maximum temperature in July.

Table 1-1 identifies the meteorological data from the Tri-Cities Regional Airport for the year 2000. Table 1-2 identifies the wind speed and direction from the NFS meteorological monitoring system. A meteorological monitoring system (wind speed, wind direction and differential temperature) is located on site just east of Building 305. The sensors are located at two levels on an approximately 120-foot high tower. The data is transmitted from a data logger at the base of the tower to a computer, which archives data daily. An independent backup meteorological system is located on the third floor of Building [redacted] Backup electrical power (UPS system) is available for both systems. The wind speed and direction data are used in projecting doses from airborne radioactivity releases.

The average annual rainfall in the Erwin area is 41 inches, and the average annual snowfall is 16 inches. Prevailing winds tend to be from the southwest following the orientation of the valley, southwest to northeast. The 30-year average wind speed is 6.9 mph or 3.1 m/s (NFS Env. Report, Dec. 1996).

NON-PROPRIETARY INFORMATION
Table 1-1
Meteorological Data for 2000
BRISTOL-JHNSN CITY-KPT, TN (TRI)

LATITUDE: 36° 28' 47" N | LONGITUDE: 82° 23' 56" W | ELEVATION (FT): GRND: 1556 BARO: 1556 | TIME ZONE: EASTERN (UTC+5) | WBAN: 13877

	ELEMENT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
TEMPERATURE °F	MEAN DAILY MAXIMUM	43.9	55.4	63.0	64.3	79.5	82.8	83.4	82.9	78.4	72.6	55.0	40.8	66.8
	HIGHEST DAILY MAXIMUM	72	75	78	82	89	91	91	91	87	81	77	67	91
	DATE OF OCCURRENCE	03	26	08	20	18+	14	10	16	11+	04+	08+	16	AUG 16
	MEAN DAILY MINIMUM	23.8	30.6	35.5	41.4	53.0	61.0	63.2	61.9	55.7	41.1	33.2	20.7	43.4
	LOWEST DAILY MINIMUM	4	16	24	30	38	44	55	54	37	26	12	4	4
	DATE OF OCCURRENCE	27	06	14	10+	16	07	02	13	17	31+	22	23	DEC 23
	AVERAGE DRY BULB	33.9	43.0	49.3	52.9	66.3	71.9	73.3	72.4	67.1	56.9	44.1	30.8	55.2
	MEAN WET BULB	30.4	38.0	43.8	47.9	60.2	65.9	67.2	66.9	61.0	49.5	39.3		
	MEAN DEW POINT	23.5	32.1	37.1	43.0	55.5	62.7	64.2	64.4	57.4	43.2	33.1		
	NUMBER OF DAYS WITH:													
	MAXIMUM ≥ 90°	0	0	0	0	0	3	1	3	0	0	0	0	7
	MAXIMUM ≤ 32°	6	1	0	0	0	0	0	0	0	0	1	6	14
	MINIMUM ≤ 32°	25	16	10	5	0	0	0	0	0	8	18	26	108
	MINIMUM ≤ 0°	0	0	0	0	0	0	0	0	0	0	0	0	0
H/C	HEATING DEGREEE DAYS	956	631	480	356	36	11	0	0	75	253	619	1053	4470
	COOLING DEGREE DAYS	0	0	0	0	80	226	263	237	144	6	1	0	957
RH	MEAN (PERCENT)	69	69	66	72	71	77	77	80	75	68	69	71	72
	HOUR 01 LST	79	80	78	83	87	92	91	92	89	86	78	77	84
	HOUR 07 LST	78	84	85	87	89	91	91	95	93	93	83	81	88
	HOUR 13 LST	57	55	52	58	50	58	60	62	55	41	54	59	55
	HOUR 19 LST	62	60	54	62	59	65	69	71	70	59	64	67	64
S	PERCENT POSSIBLE SUNSHINE													
W/O	NUMBER OF DAYS WITH:													
	HEAVY FOG (VISBY ≤ ¼ MI)	3	0	3	4	5	5	2	8	5	6	0	3	44
	THUNDERSTORMS	1	1	2	2	6	8	9	10	4	0	2	1	46
CLOUDINESS	SUNRISE-SUNSET: (OKTAS)													
	CEILOMETER (≤12,000 FT.)													
	SATELLITE (>12,000 FT.)													
	MIDNIGHT-MIDNIGHT: (OKTAS)													
	CEILOMETER (≤12,000 FT.)													
	SATELLITE (>12,000 FT.)													
	NUMBER OF DAYS WITH:													
	CLEAR													
	PARTLY CLOUDY													
	CLOUDY													
PR	MEAN STATION PRESS. (IN.)	28.48	28.52	28.40	28.34	28.38	28.45	28.38	28.45	28.42	28.57	28.42		
	MEAN SEA-LEVEL PRESS (IN.)	30.17	30.18	30.04	29.98	29.99	30.06	29.99	30.05	30.03	30.21	30.08		
WINDS	RESULTANT SPEED (MPH)	3.2	2.5	1.3	2.6	3.2	2.4	0.5	0.2	0.8	1.0	2.6		
	RES. DIR. (TENS OF DEGS.)	28	26	26	26	25	24	21	33	27	30	26		
	MEAN SPEED (MPH)	5.5	4.9	4.6	5.4	5.1	3.7	3.2	3.0	3.6	2.4	5.1	5.4	4.3
	PREVAIL. DIR. (TENS OF DEGS.)	26	28	23	26	25	23	23	24	23	36	26	24	24
	MAXIMUM 2-MINUTE WIND:													
	SPEED (MPH)	34	37	32	30	36	39	31	30	24	17	36	33	37
	DIR. (TENS OF DEGS.)	25	24	27	28	24	21	33	36	26	36	25	25	24
	DATE OF OCCURRENCE	11	14	28	17	25	17	14	09+	25	28+	09	17	FEB 14
	MAXIMUM 5-SECOND WIND:													
	SPEED (MPH)	45	45	39	38	62	41	40	54	31	22	47	39	62
	DIR. (TENS OF DEGS.)	28	24	27	27	28	20	09	29	27	31	25	25	28
	DATE OF OCCURRENCE	11	14	28+	17+	28	15	30	08	25	28	09	17	MAY 28
PRECIPITATION	WATER EQUIVALENT													
	TOTAL (IN.)	3.62	1.86	3.84	3.55	3.19	4.56	5.42	3.70	1.74	0.02	2.42	1.69	35.61
	GREATEST 24-HOUR (IN.)	1.27	0.51	1.56	1.28	0.88	1.30	2.31	1.83	0.88	0.02	1.51	0.71	2.31
	DATE OF OCCURRENCE	09-10	13-14	20-21	02-03	25	28-29	23-24	23-24	20-21	24	09	16	JUL 23-24
	NUMBER OF DAYS WITH:													
	PRECIPITATION ≥ 0.01	14	8	12	18	8	14	10	15	9	1	11	13	133
	PRECIPITATION ≥ 0.10	10	5	6	10	6	10	9	8	3	0	4	6	77
	PRECIPITATION ≥ 1.00	0	0	2	1	0	1	1	1	0	0	1	0	7
SNOWFALL	SNOW, ICE PELLETS, HAIL: TOTAL (IN.)													
	GREATEST 24-HOUR (IN.)													
	DATE OF OCCURRENCE													
	MAXIMUM SNOW DEPTH (IN.)													
	DATE OF OCCURRENCE													
	NUMBER OF DAYS WITH: SNOWFALL ≥ 1.0													

Published by: NCDC Asheville, NC

2

Table 1-2
Wind Speed/Direction Frequency Data
Data Collected at the NFS Meterological Tower, Erwin, Tennessee

		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
1991	Frequency (%)	8.0	4.5	3.5	2.4	1.7	1.8	2.8	6.1	10.3	16.5	17.4	6.4	2.5	2.5	3.5	10.3
	Avg. Speed (mph)	6.8	5.0	4.4	4.3	3.5	4.8	6.4	8.7	8.1	7.3	8.4	6.1	5.5	5.2	6.2	7.5
	Avg. Speed (m/s)	3.0	2.2	2.0	1.9	1.6	2.1	2.9	3.9	3.6	3.2	3.8	2.7	2.4	2.3	2.8	3.4
1992	Frequency (%)	6.3	4.1	2.8	2.0	2.0	1.8	3.9	6.9	12.3	19.0	10.4	4.6	2.1	2.4	5.5	13.9
	Avg. Speed (mph)	6.0	5.1	4.4	4.1	3.8	4.5	6.7	7.8	7.7	8.1	8.3	7.6	6.0	5.1	7.2	8.0
	Avg. Speed (m/s)	2.7	2.3	2.0	1.8	1.7	2.0	3.0	3.5	3.4	3.6	3.7	3.4	2.7	2.3	3.2	3.6
1993	Frequency (%)	6.0	4.0	3.0	2.0	1.6	1.9	3.7	6.7	12.1	18.1	13.2	5.5	3.1	2.8	5.4	11.2
	Avg. Speed (mph)	5.8	4.7	4.2	3.9	3.8	4.7	6.4	7.3	7.7	7.6	8.8	8.9	5.9	5.9	6.8	8.0
	Avg. Speed (m/s)	2.6	2.1	1.8	1.7	1.7	2.1	2.8	3.2	3.4	3.3	3.9	3.9	2.6	2.6	3.0	3.5
1994	Frequency (%)	6.7	3.9	2.9	2.1	1.7	1.9	2.9	6.3	10.3	19.4	13.6	5.9	2.7	2.2	4.6	12.8
	Avg. Speed (mph)	5.9	4.9	4.3	3.6	3.4	3.6	5.5	7.2	7.8	7.6	8.1	7.1	5.7	5.4	6.7	7.7
	Avg. Speed (m/s)	2.6	2.2	1.9	1.6	1.5	1.6	2.4	3.2	3.5	3.4	3.6	3.2	2.5	2.4	3.0	3.4
1995	Frequency (%)	7.9	4.5	3.0	2.4	1.7	1.9	3.9	6.9	12.0	17.5	10.8	5.1	2.3	2.4	4.4	13.4
	Avg. Speed (mph)	5.7	4.8	4.1	3.5	3.3	4.3	6.0	8.0	7.6	7.3	7.9	6.8	5.4	5.2	6.3	7.6
	Avg. Speed (m/s)	2.6	2.1	1.8	1.6	1.5	1.9	2.7	3.6	3.4	3.3	3.5	3.1	2.4	2.3	2.8	3.4
'91-'95	Freq (%)	7.0	4.2	3.0	2.2	1.7	1.9	3.4	6.6	11.4	18.1	13.1	5.5	2.5	2.5	4.7	12.3
	Sp (mph)	6.0	4.9	4.3	3.9	3.6	4.4	6.2	7.8	7.8	7.5	8.3	7.3	5.7	5.3	6.6	7.8

1.3.2 Winds and Storms

Severe storm conditions are rare in the Erwin region, which is east of the center of tornado activity, south of most blizzard conditions, and too far inland to be affected by hurricane activity. National Oceanic and Atmospheric Administration (NOAA) regional data state a maximum sustained wind of 50 mph in 1951, and a peak wind gust of 86 mph in 1995. Wind data from the NFS Site collected over approximately the past three years indicate a maximum sustained wind of 29 mph. Considering that the BPF was determined to meet the 1999 Standard Building Code (SBC) with a design wind load of 70 mph, winds and storms are not of significant concern to BPF operations.

However, due to the fact that design basis high winds could cause an inadequately designed building to collapse, leading to a radiological or chemical release that could exceed the exposure criteria defined in Section 7, the structural features of the BPF required to meet SBC 1999 code requirements for wind load factors will be designated items relied on for safety (IROFS) in Section 6. Appropriate management measures will be applied to ensure that the BPF was designed, built, and is maintained to building code requirements.

1.3.3 Tornadoes

The only tornado reported in Unicoi County in the last 50 years occurred July 10, 1980. According to NOAA event data, no deaths occurred and only 12 injuries were reported. According to the *Johnson City Press*, high winds caused damage in the north side of Erwin, and in the Limestone Cove area northwest of Unicoi. These areas are more open than the NFS Site, which is in a fairly narrow valley. The adjacent Tennessee counties of Washington and Carter reported two tornadoes each in the last 50 years, which is also very infrequent.

The annual average number of tornadoes per 10,000 square miles for the State of Tennessee from 1950 – 1995 as reported by NOAA is 2.9. This equates to an average probability of 6.4 E-6 per square mile per year. Since the NFS Controlled Area is 0.047 square miles, the average probability is 3.0 E-7 per year for a direct hit at the NFS Controlled Area. This probability is considered conservative since the NFS Controlled Area (0.047 sq. miles) is not an open area, but bounded by mountain ranges that run in a southwest to northeast direction indicative of Northeast Tennessee topography. The NOAA statistics bound the entire state of Tennessee, of which a majority of the area is more open topography than Northeast Tennessee. Therefore, the probability of a tornado occurring is even less at the NFS Controlled Area.

Considering the low probability of a tornado striking the NFS Site, of tornadoes developing in the Unicoi County area, and even lower probability of a tornado developing at the NFS Site, a damaging tornado is not considered a significant

concern for site operations. In the event that a tornado did occur on site protective actions would be implemented in accordance with the NFS Emergency Plan.

1.3.4 Lightning

NFS performed a lightning risk analysis for the facilities near the BPF in accordance with the Lightning Protection Code (NFPA 780) and determined that the area was at a moderate to severe risk of being damaged by lightning. This ranking is fourth out of five levels with 'severe' being the highest (fifth level). NFS will provide lightning protection in accordance with NFPA 780 for the BPF, therefore, lightning strikes would not be a significant concern for BPF operations.

1.4 HYDROLOGY

A natural spring (Banner Spring) originates on the NFS Site. Water from Banner Spring forms Banner Spring Branch, which flows across the site into Martin Creek. Martin Creek flows along the northern boundary of the site and empties into North Indian Creek, which empties into the Nolichucky River about 4,000 feet downstream from the site.

Flood

The NFS Site is not within the 100-year flood plain of the Nolichucky River (Evaluation of 100-year Flood Plain Data recommended per Section 3.4.3.2 of NUREG 1520). As shown in Figure 1-5, the northern portion of the site is within the 100-year flood plain of Martin Creek. Figure 1-5 shows that the north wall of Building 333 (BPF) is on the boundary of the 100-year flood plain of Martin Creek, therefore, the BPF would not be directly impacted by a 100-year flood.

Because the site is fairly level, the depth of flooding over areas at an elevation below 1640 feet above sea level (northern section of the site) would be 1 to 2 feet (Dewberry & Davis, Martin Creek Flood Plain, 1997). This level of flooding could cause a loss of power, or loss of the various utility and auxiliary systems supporting BPF operations. However, loss of power or loss of BPF support systems have been evaluated and determined to be in compliance with the performance requirements. Therefore, a 100-year flood would not have significant consequences for BPF operations.

1.5 GEOLOGY AND SEISMOLOGY

1.5.1 Geology

The NFS Site is in the Blue Ridge physiographic province of northeastern Tennessee. The area topography consists of a series of alternating valleys and ridges that have a northeast-southeast trend, with NFS in a valley. The

topography of the valley is the result of stream erosion of softer shales and limestones. The bedrock strata in the valley is consolidated.

1.5.2 Seismology

For seismic application, the NFS site is in the moderately active Appalachian Tectonic Belt with a Seismic Zone 2 designation, indicating moderate damage corresponding to Intensity VII on the Modified Mercalli scale (**Figure 1-6**). There is no evidence of capable faults in the immediate area of NFS.

In 2001, Performance Technologies, Inc. (PTI) conducted a seismic analysis of the NFS Site, in accordance with Condition S-28 of NRC License SNM-124. This analysis determined that there is no evidence of geologically recent fault displacements that would be associated with capable faults in the NFS Site or surrounding region. For the 1.E-3 annual probability of exceedance (1000 year return period), the analysis determined horizontal component of ground motion at the NFS Site for a safe shutdown earthquake is a peak ground acceleration of 0.06 gravity. The vertical acceleration is two thirds of the horizontal or 0.04 gravity.

The main BPF structure and internal components are being built to meet the requirements of ASCE 7-98 (Minimum Design Load for Buildings and Other Structures, American Society of Civil Engineers, 2000), per the requirements of the Standard Building Code (1999 Edition of Southern Building Code Congress International). The ASCE 7-98 seismic design loads are based on an earthquake with a significantly higher return period than that evaluated by the PTI report (2,475 year return period), and significantly higher maximum short period acceleration (0.21 g maximum in PTI report compared to 0.31 g maximum for ASCE 7-98). Considering the low seismic activity rating for the Erwin area, and crediting the stringent seismic design requirements for the BPF, an earthquake would not be expected to result in significant consequences compared to 10 CFR 70.61 levels.

However, in the event of a design basis earthquake, an inadequately designed building could collapse, leading to a chemical or radiological release that could exceed the exposure criteria defined in Section 7. Therefore, the structural features of the BPF design that are required to meet the SBC 1999 code requirements for seismic acceleration are designated as IROFS in Section 6. Appropriate management measures are also applied to ensure that the BPF was designed, built and is maintained to building code requirements.

Figure 1-5

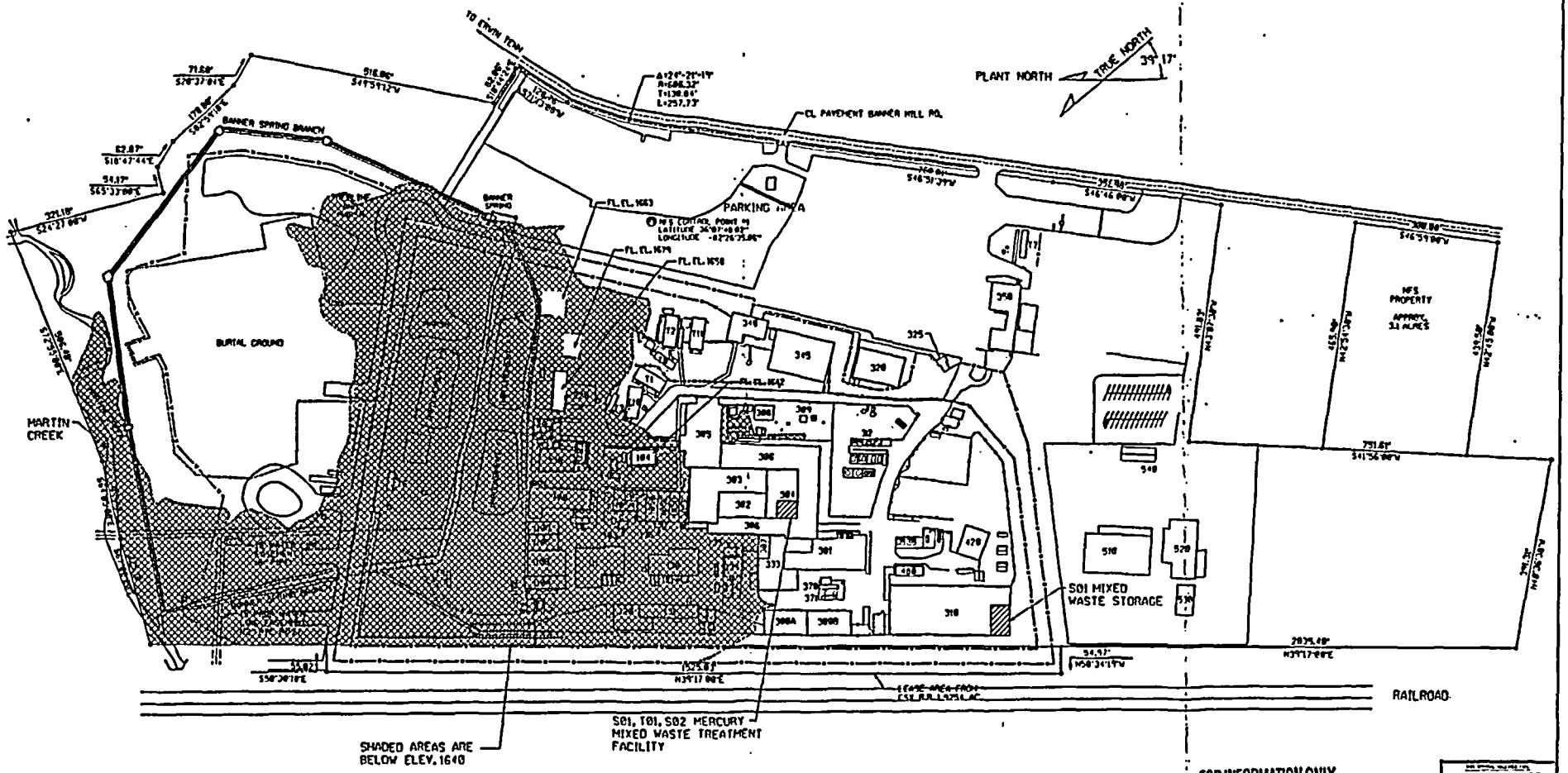

TO ERWIN TENN
PLANT NORTH
TRUE NORTH
39° 17'
CL PAVEMENT BANNER HILL RD.
BANNER SPRING BRANCH
PARKING AREA
BURIAL GROUND
MARTIN CREEK
NFS PROPERTY
APPROX. 33 ACRES
S01 MIXED WASTE STORAGE
RAILROAD
SHADED AREAS ARE BELOW ELEV. 1640
S01, T01, S02 MERCURY MIXED WASTE TREATMENT FACILITY
FOR INFORMATION ONLY
NUCLEAR FUEL SERVICES, INC.
APPROXIMATE 100 YEAR FLOOD PLAIN
000-C0083-D

Figure 1-6
Seismic Zone Map of the United States

2.0 FACILITY DESCRIPTION

2.1 SITE FACILITIES

The BPF will be built mainly within Building [redacted] which is in the Protected Area of the site. Other site facilities consist of numerous small buildings, the majority of which are within the Controlled Area. The administration buildings and guardhouses consist of glass and concrete structures, and structures made of local brick. The process and process support buildings are predominantly constructed of precast concrete panels, and white painted cement block. Metal "Butler-style" buildings are also used to house process support facilities such as respirator cleaning and testing, offices, decommissioning activities, containers of low level radioactive materials, equipment and supplies.

Buildings within the NFS plant have been designated with numbers and names as shown in **Figure 1-4**. Descriptions of the principal activities for the buildings are provided below. Also, **Table 2-1** identifies the Bulk Chemical Storage areas in the NFS plant. Building layouts and more detailed process descriptions for site facilities are provided in Chapters 10 and 15 of License SNM-124.

Warehouse Facilities

Warehouse and material storage facilities include Buildings [redacted] south end of [redacted] southeast portion of [redacted] south and east sections of [redacted] and the Industrial Park Facility (IPF) Warehouse. The IPF Warehouse is a general-purpose warehouse used primarily for storage of low-level radioactive waste in approved shipping containers (Section 15.11 of SNM License 124).

Maintenance Facilities

The maintenance facilities reside in Buildings [redacted] and the east section of [redacted] The plant's primary maintenance facility is in Buildings [redacted]

Materials Staging and Medical Facility

Building [redacted] is a multi-function facility which includes medical facilities (e.g., medical records, examining rooms, Fitness-for-Duty testing facility, and emergency decontamination showers), the invivo counting facility, and the shipping / receiving / staging area.

Highly Enriched Uranium Recovery Facility (HEURF)

The HEURF was comprised of four buildings formerly referred to collectively as the [redacted] Complex. The four buildings that comprised the [redacted] Complex were: [redacted] (low-bay area) which contains change rooms and offices; [redacted] which contained the process exhaust ventilation fans; [redacted] which was the production area; and [redacted]

which also was a production area and a vault-type storage area. The [redacted] Complex has been decommissioned and Building [redacted] is the only building that remains. Building [redacted] is where the previous HEU processes and the HEU to LEU downblending operation were conducted on site. The Building 233 downblending operation is authorized per Sections 6.5.4 and 1.5.1.4 of License SNM-124, and is essentially the same as the BPF downblending operations described in Section 3.4 of this report.

Service Building and NDA Laboratory

Building [redacted] contains change rooms, lunch rooms, First-Aid Station, office area, vending food storage, laundry facility, and NDA laboratory.

Research and Development Laboratories

The Research and Development (R&D) Laboratories are located in Buildings [redacted] and [redacted] These buildings contain facilities for conducting engineering studies and process evaluations for environmental remediation projects and for new business opportunities for NFS. These studies and evaluations may involve separating hazardous material and radioactive material, recovering resources from hazardous and/or radioactive waste, and treating hazardous and/or radioactive waste material. They may also involve R&D of chemical and radioactive material processing and manufacturing technology in support of new business development. These laboratories also conduct laboratory analyses in support of the engineering studies, as well as for customer and NFS process or waste materials. These activities are also licensed by the State of Tennessee.

Respirator Facility

Building [redacted] houses the respirator facility which includes a respirator laundry; an inspection, testing, and quality assurance area; a fit-test facility; and offices for individuals involved in these activities.

Low Enriched Uranium Recovery Facility (LEURF)

In the past, the LEURF was located in Building 111. The process equipment has been removed, but the process described in Chapter 15 of License SNM-124 could be installed again should NFS obtain a need for this type of service. This building is also the location for natural and depleted uranium processing under NFS' State of Tennessee source material license. The current principal activities for this building are to prepare and stage containers of low level radioactive waste (LLW) generated by ongoing plant decommissioning activities, prior to shipping to a disposal facility, and storage of uranium solutions.

Administration Buildings

Buildings [redacted] (east annex), [redacted] (north end), [redacted] and [redacted] house offices and computer facilities. Buildings [redacted] and [redacted] are the main security check points for vehicles and persons entering and leaving the site's Protected Area.

Central Analytical Laboratory

Building 105 and the northwest portion of Building [redacted] contain the plant's Central Analytical Laboratory. This laboratory handles samples from all plant processing facilities (HEU, LEU, natural U, and depleted U), scrap recovery facilities, waste water treatment facilities, and select environmental monitoring programs.

Plant Utilities

Building [redacted] houses non-radioactive plant utility services. This building contained uranium processes in the past, and covered fixed radioactive contamination exists. The utilities which originate in this building are compressed air, deionized water, and steam.

[redacted] Complex

This facility is comprised of eight buildings, referred to collectively as the [redacted] Complex. Buildings [redacted], [redacted] contain unit operations involving highly enriched uranium. Building [redacted] also contains offices, change rooms, a security alarm station, and a portion of the Central Analytical Lab. Building [redacted] contains process support equipment, non-radioactive chemical process storage tanks, offices, non-nuclear stores warehouse, and a mixed waste treatment process. Building [redacted] contains process support equipment, process exhaust ventilation scrubbing equipment, vault-type storage area, shipping and receiving area, and equipment maintenance area. Building [redacted] contains process exhaust ventilation fans. Building [redacted] contains the gaseous effluent sampling equipment for the main plant stack. The processes in this complex are more fully described in Chapter 15 of License SNM-124.

Building [redacted] previously housed uninstalled process equipment. This building is the location for the BPF, which is made up of HEU processes and HEU to LEU uranium downblending operation.

Pond 4 Containment Building

Building [redacted] provided weather protection for remediation of portions of a former on-site disposal area designated as Pond 4. Building [redacted] has been decommissioned and is no longer standing. The Pond 4 disposal area also extends to areas outside of Building [redacted] This facility is also licensed by the State of

Tennessee for handling waste, soil, and debris contaminated with source materials.

Waste Water Treatment Facility (WWTF)

Waste water treatment is conducted in Buildings [redacted] and [redacted]. Building [redacted] contains the process for treating liquid effluents generated by the process facilities, R&D laboratories, laundry, decommissioning activities, and analytical laboratory. The effluents are treated to meet the requirements of 10 CFR Part 20 and a National Pollutant Discharge Elimination System permit issued to NFS by the State of Tennessee. Treated effluent is discharged to the Nolichucky River. Building [redacted] processes groundwater generated from decommissioning activities. The groundwater is treated to meet the requirements of 10 CFR Part 20, and a pretreatment permit issued to NFS by Erwin Utilities. Treated groundwater is discharged to the Erwin Publicly Owned Treatment Works (POTW).

Motor Pool

Building [redacted] is used for storage and maintenance of large earth-moving equipment.

Uranyl Nitrate Building (Building [redacted])

Low-enriched uranyl nitrate liquid is stored in Building [redacted] in tanks. Support facilities for unloading uranyl nitrate liquid from shipping packages are part of the building. Low-enriched uranyl nitrate liquid will be eventually processed in the Oxide Conversion Building (Building [redacted] future facility). The Uranyl Nitrate Building also provides storage and load-out for natural uranyl nitrate solution.

The Guard/Security Building (Building [redacted]) contains no radiological controlled material and is strictly a support facility.

Bulk Chemical Storage

The following table presents the location, contents, and estimated volumes and pressures of the chemicals stored in the Bulk Chemical Storage Area.

Table 2-1
Bulk Chemical Storage

Chemical	Quantity (gallons)	Storage Location	Classification	Pressure	Comments
Ammonium Hydroxide	[redacted] [redacted]	BCSA BCSA	Corrosive, Toxic, Explosive, Irritant, EPA Listed Hazardous Waste	Expected 1-1.5 psig	Tanks contain a nitrogen blanket for quality control purposes
Argon	[redacted] lb.	East side Bldg. 310	Asphyxiant	90 psig	
Carbon Dioxide	[redacted] lb.	Outside Bldg. 135	Asphyxiant	300 psig	
	[redacted] lb.	Outside Bldg. 333	Asphyxiant	300 psig	
Diesel Fuel	[redacted] [redacted] [redacted]	BCSA Burial Ground Bldg. 410	Irritant, Combustible, Neurotoxin	Atmospheric	
Fuel Oil	[redacted] [redacted]	Bldg. 110A Bldg. 306	Irritant, Combustible, Toxic	Atmospheric	
Gasoline	[redacted]	Across from BCSA	Explosive, Flammable	Atmospheric	
Hexanol (inactive)	[redacted]	BCSA	Combustible, Irritant, Corrosive	Atmospheric	
Hydrogen (gaseous)	6 tubes [redacted]	East Side Bldg. 310	Compressed Gas, Explosive, Flammable	1700 psig	After tube fill up 1800 psig expected
Hydrogen (liquid)	[redacted]	East Side Bldg. 310	Compressed Gas, Explosive, Flammable	144 psig	
Hydrogen Peroxide	[redacted] [redacted] drum	Bldg. 330 (2 tanks) BCSA	Corrosive, Oxidizer, Irritant	Atmospheric	
Isopropyl Alcohol	[redacted]	BCSA	Flammable, Irritant, Toxic	1-1.5 psig	Tank contains a nitrogen blanket for quality control purposes
Kerosene	[redacted] [redacted]	BCSA Bldg. 410	Irritant, Flammable, Neurotoxin	Atmospheric	
Liquefied Petroleum (LP) Gas (Propane)	[redacted]	Front of BCSA	Explosive, Flammable, Asphyxiant, Irritant, Compressed Gas	Vendor states expected pressure to be 200-300 psig	

Chemical	Quantity (gallons)	Storage Location	Classification	Pressure	Comments
Methanol (inactive)	[redacted]	BCSA	Explosive, Flammable, Irritant, Neurotoxin, EPA Listed Hazardous Waste	Atmospheric	
Methyltrichlorosilane	[redacted]	West Side Bldg. 301	Flammable, Explosive, Irritant	No expected pressure	Stored in 55-gallon drum
Nitric Acid	[redacted]	BCSA	Corrosive, Toxic, Oxidizer, Irritant, EPA Listed Hazardous Waste	Atmospheric	
Nitrogen (Liquid)	[redacted]	East Side Bldg. 310	Compressed Gas, Asphyxiant	120 psig	
	[redacted]	South Side Bldg. 350	Compressed Gas, Asphyxiant	24 psig	
	[redacted]	West Side Bldg. 301A	Compressed Gas, Asphyxiant	24 psig	
Sodium Hydrosulfide	[redacted]	Bldg. 330	Corrosive	Atmospheric	
Sodium Hydroxide	[redacted] [redacted]	Bldg. 330 BCSA	Corrosive, Irritant, Toxic, Explosive	Atmospheric	
Sulfuric Acid	[redacted]	Bldg. 330	Corrosive, Reactive, Oxidizer	Atmospheric	Has a filtered vent
Tributyl Phosphate	[redacted]	BCSA	Irritant, Hemotopoletic, Neurotoxin	Atmospheric	
Uranyl Nitrate Tank Trailer	[redacted]	West of Bldg. 333	Corrosive, Irritant	Atmospheric	

BCSA: Bulk Chemical Storage Area (Section 15.10.5.3 of License SNM-124)

Potential BCSA Hazards are addressed in Section 4.2.6 of this report.

2.1.1 Off-Site Support

NFS has established emergency assistance agreements with the following agencies: Unicoi County Memorial Hospital, Johnson City Medical Center Hospital, Erwin Fire Department, Unicoi County Sheriff's Department, and Quality Care Ambulance Service. The locations of these agencies are shown in Figure 1-3. During emergencies, off-site agencies requiring access to the Protected Area are met at the vehicle entrance gate and escorted from the time they enter the gate until they leave.

Unicoi County Memorial Hospital and Johnson City Medical Center Hospital

Hospital staff are trained to respond to emergency situations at NFS. Medical treatment will be provided for injured personnel, including victims of radiological

exposure or contamination. NFS may provide support to the hospital for handling and detecting contamination. Agreements with Radiation Emergency Assistance Center/Training Site (REAC/TS) are also in place to assist, when necessary.

Erwin Fire Department

Fire department personnel are trained to respond to emergency situations at NFS. NFS provides training in contamination control and monitoring to fire department personnel.

Quality Care Ambulance Service

Ambulance personnel are trained and certified to provide emergency transport services. NFS provides training in contamination control and monitoring to ambulance personnel.

Unicoi County Sheriff's Department

Notification of an emergency condition and its classification is made to the Sheriff's Department. The purpose of this notification is to provide local authorities, through the Sheriff's Department, with advance notification of a potential need for off-site support or protective action measures. In the event telephone communication is disrupted, notification can be made via two-way radio.

2.2 BPF DESCRIPTION

Figure 2-1

Figure 2-2

Figure 2-3

Figure 2-4

Figure 2-5

Figure 2-6

Figure 2-7

Figure 2-8

Table 2-2
BLEU Preparation Facility
Building Dimensions and Ventilation System Sizing

Area Description	Floor Space (sq. ft.)	Roof height (ft.)	Bldg. Volume (cu. ft.)	HVAC Supply Air (cfm)	Design Recirc. Air Changes per hour	Room Air Exhaust (cfm)	Fresh Air Changes per hour
Solvent Extraction							
1st floor	1,624	20	32,480				
2nd floor	1,624	12	19,488				
3rd floor	804	12	9,648				
Chimney Area	425	49	20,825				
TOTAL	4,477		82,441	39,000	28.3	6,250	4.0
Main Building							
processing area at 0' elevation	2,108	35	73,789				
processing area at 0' elevation beneath mezz.	809	16	12,936				
HEU Offices at 0' elevation	264	9.67	2,553		8-10		
walkway to SX at 5' 0" elevation	120	30	3,600				
area above offices at 9' 8" elevation	827	10.333	8,545				
mezzanine level at 16' 0" elevation	1,238	19	23,513				
high security storage area at 17' 6" elevation	1,104	17.5	19,320				
elevated platform at 20' elevation	588	15	8,813				
TOTAL	7,057		153,068	65,000	25.1	10,500	4.0
LEU Area							
LEU Tank Area	537	35	18,778				
LEU Operating Area	444	16	7,100				
LEU Offices/Lockers	528	9.67	5,106		8-10		
TOTAL	1,508		30,983	13,500	25.4	2,150	4.0
Other Areas							
Electrical room	308	14	4,312				
Mechanical room	924	14	12,936				
Discard Dike room (est.)	480	20	9,600				

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2.3 BPF AUXILIARY AND UTILITY SYSTEMS

The site auxiliary and utility systems are described below, with reference to how they support BPF operations.

2.3.1 Electrical

Electrical power is supplied to the site by Erwin Utilities from the Tennessee Valley Authority. Erwin Utilities is municipally owned and operated and has a single electrical substation approximately one mile northwest of the NFS Site. There are three electrical substations (134, 134A and 134B) in the NFS plant which are jointly owned by Erwin Utilities and NFS. Utility power distribution to the substations is owned and maintained by Erwin Utilities. Power is distributed throughout the NFS plant primarily via overhead cable.

Electrical power for BPF operations (primary and auxiliary systems) is provided directly from the nearby substation (134B) and related switchgear. Two power feeds are provided, one to feed the existing 78 slot, 1200 amp, motor control center (MCC) and a second feed for the HVAC and related loads. Primary distribution will be accomplished through the MCC. Secondary distribution beyond the MCC will consist of step down transformers and distribution panels to provide the required voltage levels. Cable runs will utilize conduit runs and cable trays. Control signal conductors will be separated from power system conductors to reduce electromagnetic interference (EMI).

2.3.2 Emergency Power

Site emergency power is available from Uninterruptible Power Supply UPS-1 located in Building [redacted] Automatic Transfer Switch ATS-1 detects the loss of utility power, transfers load to the batteries, sends a start signal to the generator, transfers the load to the generator when an appropriate output voltage has been reached, and transfers back to utility power after utility power has been restored for a predetermined time. The automatic transfer switch then allows the generator to operate for a predetermined cool-down period prior to shutdown. The automatic switchover feature ensures continuous criticality detection and other surveillance during the absence of commercial power. For the BPF, the UPS-1 system provides emergency power to the criticality alarm system, fire alarm systems, security systems, programmable logic controller (PLC) panels, radiation detectors, and lighting.

The Building [redacted] PS-1 is rated at 100 kVA with battery backup and a 225 kW, 3 phase, 480 VAC diesel-driven generator.

2.3.3 Compressed Air

Two air compressors are centrally located within the main plant, providing a total capacity of 1,475 cfm of compressed air at 100 psig (see Section 15.10.5.10 of License SNM-124). One unit serves as a backup to the other in order to provide a constant supply. Air exiting the compressors passes through a receiving tank, a pre-filter desiccant air dryer, and after filter prior to distribution. Compressed air utilized within the plant areas is also filtered at the point of use.

Compressed air for the BPF is supplied from the plant air supply system. There is an automatic shut off valve where compressed air enters Building [redacted] hat closes when there is low pressure in the supply header. The compressed air distribution header is routed through the building at an elevation above the processes to prevent backflow from the building processes to the compressed air system should the system lose pressure.

2.3.4 Nitrogen

Nitrogen is supplied to the BPF from the utility services main nitrogen supply system and piped to the individual users in the building as required (See Section 15.10.5.2 of License SNM-124). There is an automatic shut off valve where nitrogen enters the building that closes when there is low pressure in the supply header. The nitrogen distribution header is routed through the building at an elevation above the processes to prevent backflow from the building processes to the nitrogen system should the nitrogen system lose pressure.

2.3.5 Nitric Acid

Nitric acid is supplied to the BPF from the bulk nitric acid tank using existing pumps. A header is routed from the discharge of the pumps to the building and distributed through the building by means of a nitric acid supply distribution header. Local switches and timers are provided to pressurize the nitric acid supply distribution header on demand. Spring-loaded valves are provided at the local user sites to provide isolation and prevent backflow. The nitric acid header and distribution lines into the BPF are stainless steel pipe.

2.3.6 Hydrogen Peroxide

Hydrogen peroxide is supplied to the BPF from the bulk hydrogen peroxide drum using existing pumps. A line runs from the current header in the 300 Complex to the building and distributes hydrogen peroxide through the building by means of a distribution header. Local switches are provided to pressurize the hydrogen peroxide supply distribution header on demand. Spring-loaded valves are used at the local user sites.

2.3.7 Water Systems

Treated water is supplied to the NFS plant by Erwin Utilities. The pressure for the system serving the NFS plant has been measured at 100 psig static. Flow through the system at 1,400 gallons per minute shows a residual pressure of 50 psig.

The Erwin Utilities treated water system supplies the NFS plant needs for process water, potable water, deionized water, and fire protection water. The fire protection water system at NFS is described in Section 10.5 of License SNM-124. A credible failure of the supply for process water, potable water, and deionized water is considered to be a break in the supply line serving the majority of the NFS plant. Ventilation scrubbers and cooling tower water loops are designed to allow short-term operation until a break is repaired.

Process Water

Process water for the BPF ties into a plant process water line downstream of an in-line backflow preventer. The process water is distributed through a process water supply distribution header. There is an automatic shut off valve where process water enters the building that closes where there is low pressure in the supply header. The process water is routed through the building at an elevation above the processes to prevent backflow from the building to the utility.

Process Cooling Water

Process cooling water for the BPF is supplied to the building from a closed loop piping system that circulates cooling water through condensers and other pieces of equipment in the BPF. The cooling water is distributed through a cooling water supply distribution header. Heat is removed from the cooling water loop by a heat exchanger in the Mechanical Room. The heat exchanger is part of another closed loop system containing a propylene glycol/water mixture that is cooled by an air cooler mounted on the Mechanical Room roof. Makeup water for this system comes from the process water downstream of an in-line backflow preventer.

Deionized Water

Deionized (DI) water is supplied to the BPF from the Building 130 services area and distributed through a DI water supply distribution header (see Section 15.10.5.8 of License SNM-124). There is an automatic shut off valve where DI water enters the building that closes when there is low pressure in the supply header. The DI water distribution header is routed through the building at an elevation above the processes to prevent backflow from the building to the utility.

2.4 LIGHTNING PROTECTION SYSTEM– NFPA 780

NFS performed a lightning risk analysis for the facilities near the BPF in accordance with the Lightning Protection Code (NFPA 780) and determined that the area was at a moderate to severe risk of being damaged by lightning. This ranking is fourth out of five levels with 'severe' being the highest (fifth level). NFS will provide lightning protection in accordance with NFPA 780 for the BPF.

2.5 VENTILATION SYSTEMS

Plant Ventilation Systems

The plant ventilation systems can be functionally separated into two categories: the heating, ventilation, and air conditioning (HVAC) systems and the process exhaust ventilation systems (PEVS) (Section 15.10.5.12 of License SNM-124). The HVAC systems are designed and operated during processing to maintain a clean and conditioned air supply to all areas of the NFS plant. The PEVS provides air flow from areas of lesser potential contamination to areas of higher potential contamination, confines and contains air streams containing radioactive constituents, and minimizes potential accumulation of contamination within the air handling duct work. Effluent from areas with the potential for containing particulate uranium has HEPA filtration. Effluent from wet process areas is cleaned by a scrubber (Figure 2-9).

BPF Ventilation Systems

There are four BPF ventilation systems: Process Exhaust Ventilation system, Hydrogen Ventilation system, Building Zone Ventilation system, and HVAC system.

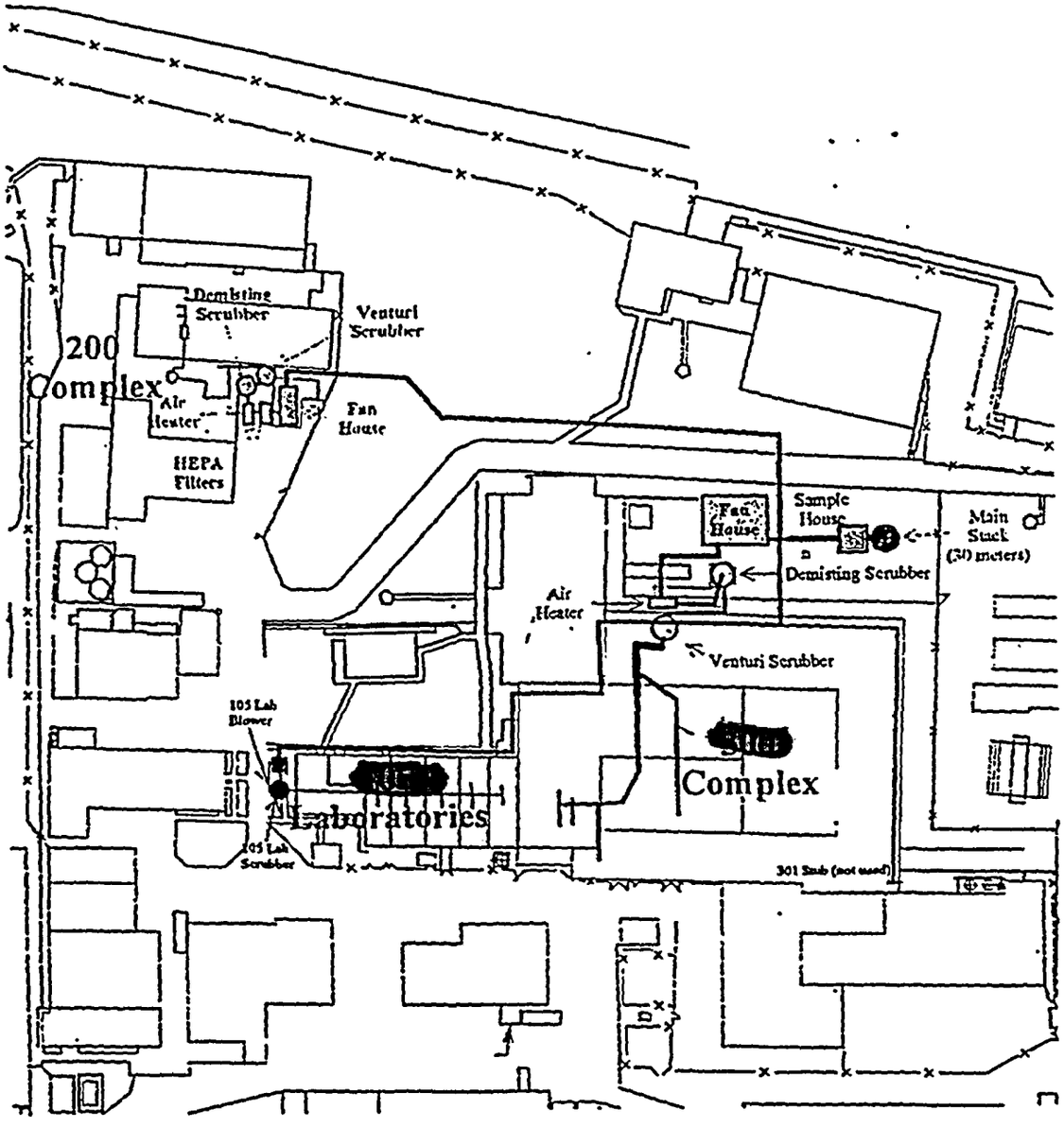
The BPF process exhaust ventilation system provides local processing/cleaning of the off-gas from the BPF processes prior to discharge to the environment. Effluent from the dry processes is HEPA filtered. The design provided sufficient airflow to meet or exceed 125 linear feet per minute (fpm) airflow requirement at enclosure openings. Ducts were sized such that airflow velocity is 1,500 fpm. Effluent from the wet processes, nitric acid and caustic systems in the BPF is routed to a scrubber. The scrubbed and filtered off-gas ventilation ducts come together and one duct line takes the effluents to the plant stack for discharge.

The dissolution of UAl by caustic solution generates hydrogen gas. The off-gas from these dissolvers is diluted with air from outside the building such that the lower explosive limit (LEL) of a hydrogen/air mixture is never reached. This effluent stream is HEPA filtered and discharged through a BPF local stack.

A separate ventilation system is used to ensure that the BPF interior building pressure is negative relative to outside air pressure. Keeping the interior pressure negative ensures potential airborne contaminants cannot leave the building. The

system is also designed to ensure that the air sweep within the building will be from areas of lower potential contamination to areas of higher potential contamination.

Figure 2-9
Main Process Exhaust Ventilation



The BPF has three HVAC units. One unit serves the HEU area, one serves the Solvent Extraction area, and one serves the NU/LEU area. The HVAC systems are designed to make four fresh air changes per hour, with 8-10 recirculated air changes per hour in the non-process areas, and 25-30 recirculated air changes per hour in the process areas. All recycled air is filtered with pre-filters and 90-95% ASHRAE efficiency final filters. All air handling equipment is resistant to corrosion from nitric acid fumes.

2.6 RADIATION PROTECTION

NFS' comprehensive radiological protection program as defined in SNM-124 is applied to BPF operations in order to ensure compliance with the requirements specified in 10 CFR 20. The objective of the Radiological Protection Program is to keep the radiation doses to workers not only below regulatory limits, but also as low as reasonably achievable (ALARA). The ALARA Program applies to all areas of the radiation safety program, including internal and external exposure control, contamination control, facility design, facility operations, procedure development, training and work practices. The radiation protection program provides sampling, monitoring, and surveillance for radioactive materials as needed in the BPF.

Engineered and administrative controls are utilized to provide high assurance that radiation levels are controlled and radioactive material is contained. These controls include:

- Equipment engineered to minimize leakage
- Physical barriers to separate people from radioactive materials
- Ventilation systems to direct radioactive material away from personnel
- Radiological air sampling system
- Detailed procedures describing proper handling techniques
- Detailed procedures describing precautions needed during upset conditions
- Continuous training of an experienced workforce
- Use of personal protective equipment (PPE) when required
- Self surveys by all individuals leaving an area containing radioactive materials
- Frequent surveys for radioactivity by independent workers
- Frequent audits to assure adequate performance of the various systems

2.7 FIRE PROTECTION

2.7.1 Fire Protection Program

Fire protection for the BPF was determined through a Fire Hazards Analysis (FHA) and ISA consequence analysis based on National Fire Protection

Association Standards, SBC, Standard Fire Prevention Code, and Industry Practices. The FHA documents how the BPF fire protection satisfies the main objectives associated with fire prevention, fire detection and alarm, life safety, fire suppression, and fire response. In addition, the FHA documents compliance with the following applicable codes:

NFPA 10, *Portable Fire Extinguishers*
NFPA 69, *Explosion Prevention Systems*
NFPA 70, *National Electric Code*®
NFPA 72, *National Fire Alarm Code*®
NFPA 90A, *Installation of Air Conditioning and Ventilating Systems*
NFPA 91, *Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Non-Combustible Particulate Solids*
NFPA 101®, *Life Safety Code*®
NFPA 220, *Types of Building Construction*
NFPA 780, *Installation of Lightning Protection Systems*
NFPA 801, *Fire Protection for Facilities Handling Radioactive Material*
Standard Building Code, 1999 Edition.
Standard Mechanical Code

Section 3 of this ISA summary provides detailed discussion on fire hazards associated with each BPF process area.

2.7.1.1 Fire Prevention

As documented in the FHA, fire prevention is addressed through noncombustible building design requirements, fire separation requirements, combustible and hot work administrative controls, ignition source controls, and explosion prevention controls.

Building Design

The main building design uses noncombustible construction; and interior components such as piping, ducting, conduit, and applied finishes were limited to a flame spread index less than 25 and were rated as self-extinguishing by a recognized laboratory.

Tanks and Columns

Tanks and columns are made of noncombustible construction, except for the following 3 small tanks:

> One [redacted] gallon HDPE plastic tank on the second mezzanine level in the SX process area, for 0.5M nitric acid,

One [redacted] gallon HDPE plastic tank in the Mechanical Room for sodium carbonate, and

One [redacted] gallon HDPE adjustment tank in the LEU process area.

These are small tanks handling noncombustible liquids. The tanks have a flame spread index of 30 or less and do not warrant any special fire protection features.

Electrical Systems

All electrical equipment and installation methods comply with NFPA 70, *National Electrical Code*®. Electrical equipment installed within the solvent extraction (SX) area and SX chemical makeup area are rated NEMA 4X and resistant to corrosion. Electrical equipment inside the UAl dissolvers, inside vent lines, inside exhaust ventilation ducting, and inside the UAl HEPA filter unit (on the roof) are rated Class 1, Division 1.

Either physical separation or noncombustible barriers, complying with NFPA 70, are used to separate power cables and signal cables in cable trays. There are no plastic cable trays. There are some multi-tier cable trays and some vertical cable shafts (short runs).

Electrical cables are fire rated and meet UL 1685, Vertical-Tray Fire Propagation and Smoke Release Test for Electrical and Optical-Fiber Cables. Meeting these requirements shows compliance with ANSI/UL 1581 flame test criteria and qualifies the cables as LS (limited smoke) cable.

The highest voltage is 480 VAC. The largest current draw (300A) is from the HVAC system. Protection devices (i.e. thermal overload) are provided on electrical motors, based on NFPA 70 requirements. Any transformers in the electrical or mechanical room are dry type transformers, meeting NFPA 70 requirements. The electrical room contains motor control and electrical switchgear equipment. Ventilation is provided to maintain room temperature below the maximum safe operating temperature for this equipment.

Fire Separation

The HEU and LEU process areas located in the main building are classified as an H4 occupancy per the SBC. The SX process area is classified as H3 occupancy and Building 307 is classified as H2 occupancy per the SBC.

Per the H4 classification, there is no requirement to separate the HEU and LEU areas with fire rated construction. However, a noncombustible barrier wall was installed between these areas for security purposes.

Fire separation provisions for the SX process area and Building [redacted] are as follows:

- Building [redacted]s separated from adjacent areas in the BPF by interior walls and ceiling assembly which comprise a minimum 2-hour fire rated enclosure.

- The SX process area is separated from adjacent areas in the BPF with minimum 2-hour fire rated construction. Design considerations include:

  – All door openings in the fire rated wall assembly have UL-listed 1½-hour rated self-closing fire doors, which open outward for employee egress from the SX area.

  – All ducting that passes through the fire rated wall assembly (with exception of exhaust to the scrubber) are provided with minimum 1½-hour rated self-closing fire dampers, located for ease of inspection, testing, and resetting.

  – All penetrations (piping, conduit) that pass through the fire rated wall assembly are sealed with a 2-hour rated material.

The Mechanical Room and Electrical Room are separated from the LEU Area with minimum 1-hour fire rated construction. All penetrations (piping, conduit) that pass through the fire rated wall assembly are sealed with a 2-hour rated material.

Transient Combustibles

Personnel training and detailed procedures are developed and implemented to strictly limit transient combustibles to very low levels. Periodic assessments are conducted to ensure that combustible loading controls and good housekeeping practices are maintained throughout the BPF.

Hot Work

Hot work presents a potential ignition source. The primary mode of ignition is through hot sparks which, if unnoticed, can ignite low-mass combustibles such as paper, cloth, and thin plastic materials which can then proceed to ignite more massive combustibles such as electric cables, plastic ducting, etc.

Although it is an unlikely situation, the potential exists for an acetylene gas leak during hot work to enter an inlet air duct for the UM furnaces and create a flash fire and overpressure incident.

NFS has hot work procedures which require a permit and fire watch. For the BPF, an additional step has been implemented to require shutdown of the UM furnaces if any hot work using flammable gas cylinders is conducted within a 35-foot radius of the UM air inlet blowers.

External Ignition and Fire Sources

Oil

Approximately 35 feet from the north wall of the BPF are two electrical substations, which contain nine oil-filled transformers. Six of the transformers have a capacity of 125 gallons and the other three have a capacity of 80 gallons of oil. The transformers are on a concrete pad surrounded by gravel. With the size of the transformers and separation distance, these transformers do not present a fire exposure to the process operations inside the BPF.

Hydrogen and Propane Tanks

Approximately 360 feet south of the BPF there is [redacted] gallon liquid hydrogen tank and a backup bank of six horizontal tanks containing gaseous hydrogen (each tube is approximately 54 cubic feet). In the same area there is a [redacted] gallon liquefied propane gas (LPG) tank. Also, the delivery truck routes for both hydrogen and propane are approximately 350 feet from the BPF.

The primary exposure from these tanks and delivery trucks is from a BLEVE. A BLEVE creates a large rising fireball of short duration, which presents a radiant heat and burn injury exposure to people who may be outside and not in fire-rated protective clothing. A BLEVE does not produce remote overpressures and presents an insignificant thermal exposure from a property damage standpoint.

A hydrogen unconfined vapor cloud explosion (UVCE) is not a credible event due to the vapor density and dispersion characteristics of hydrogen. The LPG tank size (1,000 gallons), and location (in the open), make the likelihood of an UVCE highly unlikely. The outside hydrogen and propane tanks present an insignificant exposure to process operations inside the BPF.

Building [redacted]

The only significant exposure to the BPF processing equipment from the operations in Building [redacted] s from pressurized hydrogen gas used in the process equipment. An explosion inside Building [redacted] ould damage the fire barrier walls and ceiling assembly thus exposing the high security storage area, located on top of Building [redacted] and BPF process equipment in the HEU area to explosion overpressure damage. To address this issue, the processes in Building [redacted] comply with explosion prevention measures per NFPA 69, *Explosion Prevention Systems*.

2.7.1.2 Fire Detection and Alarm

Fire Detection

An NFPA 72, *National Fire Alarm Code*®, compliant fire detection and fire alarm system was installed to meet SBC and NFPA 101® requirements. The detection system was designed to provide automatic detection throughout the BPF. The following detector types were provided:

a. Automatic Smoke and/or Heat Detection

- At the roof level and under mezzanine levels in the HEU and LEU Process Areas
- In the Mechanical Room, Electrical Room, Offices, and Change Rooms
- In Solvent Extraction and Bulk Chemical Mixing Areas
- An inline duct smoke detector in the outlet ducting (upstream of the exhaust stack) for the building exhaust ventilation HEPA units located in the HEU process area. Operation of this detector will activate visual indication in the HEU area.

b. Continuous Linear Thermal Detection Cable for providing detection in selected areas, and for specific equipment such as:

- UAl glovebox enclosure
- UAl dissolver vent lines
- UAl HEPA filter unit on roof
- Selected electrical cable tray segments
- SX evaporator heaters
- Selected points on equipment which may be subject to overtemperature conditions

Installation includes a UL-listed or FM-approved fire alarm panel with backup power, supervisory alarms, and remote alarm transmission to a constantly attended location.

Alarm System

An NFPA 72 compliant fire alarm signaling system is installed to meet the SBC and NFPA 101®. The fire alarm system includes the following:

- Horn and strobe alarm devices located throughout all process areas as well as the office areas and equipment rooms to maximize the potential for total occupant notification.

- Manual fire alarm (MFA) pull stations, which includes a minimum of one MFA at each of the required life safety exit doors.

2.7.1.3 Life Safety

Life safety exit doors, with illuminated exit signs, and panic hardware compliant with NFPA 101, are provided for each process area and each mezzanine level. The exit doors meet the maximum travel distances specified in the FHA. Egress pathways are marked and meet minimum widths specified in the FHA.

2.7.1.4 Fire Suppression

Automatic Fire Suppression

Due to criticality safety concerns documented in the nuclear criticality safety evaluations (NCSEs) for the BPF systems, automatic water sprinkler protection is not an acceptable fire suppression option. With the fire prevention, life safety, and fire protection measures documented in the ISA summary and completion of the FHA recommendations, an adequate margin of fire safety is obtained and an SBC sprinkler protection equivalency is met.

Portable Fire Extinguishers

Portable fire extinguishers are located throughout the BPF in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*. Fire extinguishers of the type which would not cause electrical damage are installed in areas with important electrical equipment. Special 2.5-gallon F500 agent fire extinguishers are provided in the SX process area.

2.7.1.5 Fire Brigade

Presently there are approximately 30 NFS Fire Brigade members. From Sunday, 11:00 p.m. to Friday, 11:00 p.m., there is 24-hour coverage by Fire Brigade members. Availability of a minimum of five Fire Brigade members on an annualized basis is approximately 71% (120 hrs/week x 52 weeks/8,760 hrs per year). Availability during the times that HEU and SX process areas are operating (5 days a week/24 hours) is approximately 95%. All operators are trained in the use of portable fire extinguishers.

Plant Fire Brigade response in full turnout gear to the BPF is in a range of 5-8 minutes. The plant fire brigade program complies with NFPA 600, *Industrial Fire Brigades*. Members currently receive 24 hours of initial fire training and 8 hours quarterly. They also attend an annual live fire training exercise.

Backup response is from the Erwin Fire Department, which is part paid and part volunteer. Response time to the BPF in full turnout gear would range from fifteen to twenty minutes. An annual joint training drill is conducted at the plant.

Pre-Fire Plans

The NFS Fire Brigade and Erwin Fire Department pre-fire plans for the NFS plant include specific emergency response strategies for the BPF.

The general strategy regarding smoke control is to maintain the HVAC systems and building exhaust ventilation systems in operation during the initial stages of the fire. This strategy will maintain negative building pressure compared to the outside and provide initial smoke dilution.

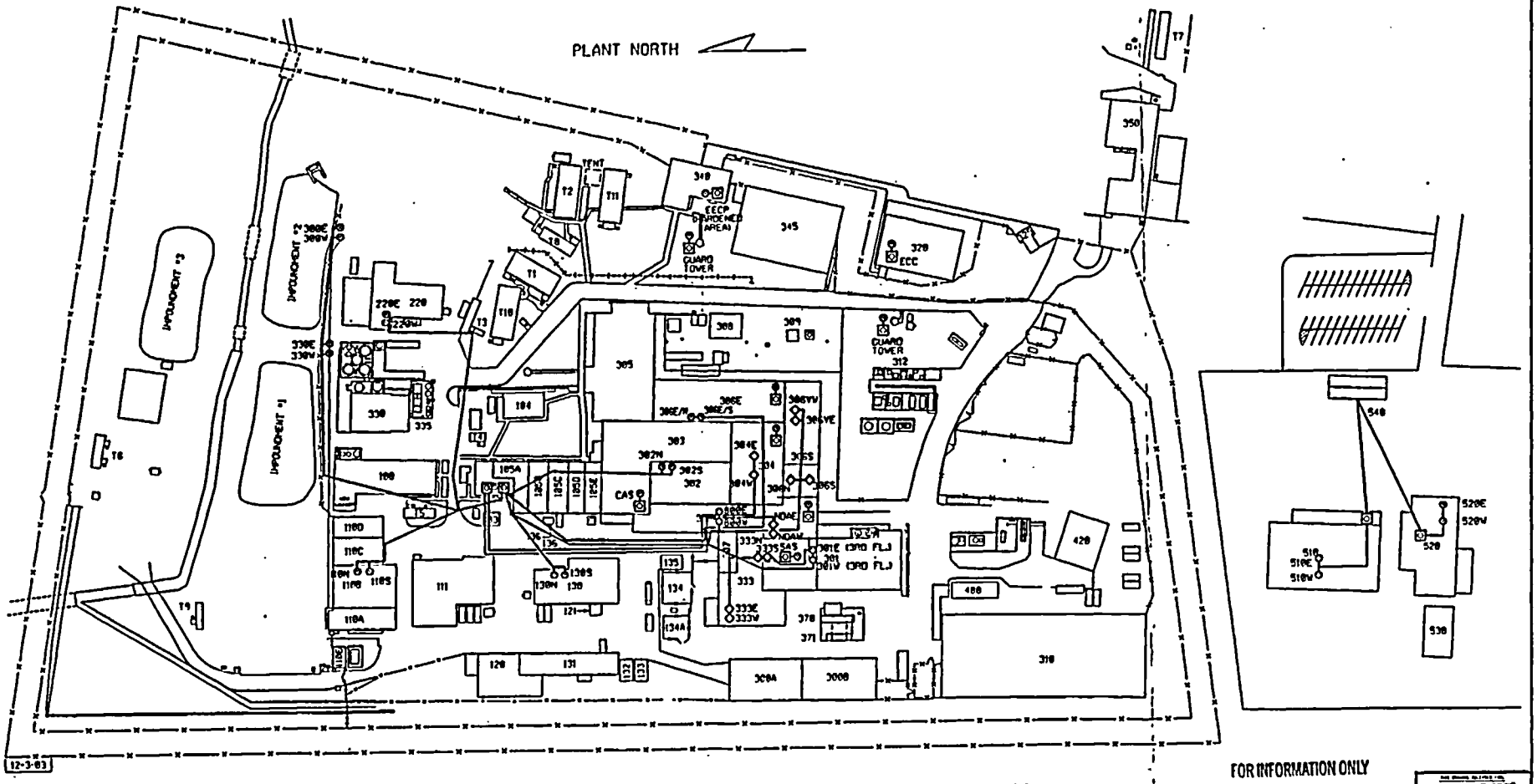
2.8 CRITICALITY DETECTION SYSTEM

The NFS Site criticality detection system meets the guidance established in ANSI/ANS 8.3, 1986, *Criticality Accident Alarm Systems* (SNM-124 Section 3.2.4.3). Monitoring is performed with Victoreen ionization chamber detector systems and Eberline GM detectors. To assure a limited number of false alarms, the system is set up with two detectors on each circuit. With this setup, a single failure will not cause alarm actuation. Alarm actuation is caused by either both detectors alarming, a single failure and the second detector alarming, or both detectors failing. The detectors are located as shown on **Figure 2-10**. The alarm trip point is set in accordance with the requirements of 10 CFR 70.24 (a)(2). Normal and standby uninterruptible power is provided as described in Sections 2.3.1 and 2.3.2.

The criticality detection and alarm system does not involve IROFS so the license requirements dictate the minimum necessary actions to ensure reliable operation of the system (License SNM-124 Section 3.2.4.3). Based on the risk assessment in Section 4.3, a criticality from any source is "highly unlikely", so a failure of the criticality detection system due to loss of power (failure of normal equipment and external emergency power supply) coincident with a criticality accident is not credible. Further, there are alarms that indicate if the detection system has failed which trigger appropriate responses per site procedures.

Calculations are performed that verify all areas of the BPF are covered by at least two detectors. In the unlikely event of a nuclear criticality accident, the alarm system would activate and all plant personnel would immediately evacuate their work area. All plant personnel are trained and knowledgeable of alarms and plant evacuation procedures. Radiation exposures from a nuclear criticality would be limited by time, distance and shielding. Upon assessment of the accident situation, a reentry team would be directed to enter certain facilities to shut-down appropriate process equipment.

Figure 2-10



FOR INFORMATION ONLY

REFERENCE DRAWING:
011-10087-D CRITICALITY/FIRE ALARM BLOCK DIAGRAM

LEGEND

- CRITICALITY DETECTOR (MODERATED EVENTS ONLY)
- READOUT
- CRITICALITY DETECTOR (METAL & MODERATED EVENTS)

BY	DATE	REVISION	LET
		AREA BLDG FACILITY UPDATED PLANT LAYOUT REVISED LEGEND & DETECTOR LOCATIONS	I
	9-10-03	REVISED PER DWG 97742	H
	9-14-03	REVISED PER DWG 98375, 98005 & 98006	G
	12-16-98	ORIGINAL ISSUE WAS 000-C0002-D	—

NUCLEAR FUEL SERVICES, INC.
EWING, TENNESSEE

CRITICALITY DETECTOR/READOUT LOCATIONS

SCALE 1"=60' | DATE 10-20-03

DRAWING NO. 000-C0008-D

FORWARD NEW REVISIONS TO THE EPC

3.0 PROCESS DESCRIPTIONS

The purpose of BPF process operations is to reduce stockpiles of surplus DOE high-enriched uranium (HEU) by downblending HEU material to LEU for use as fuel in nuclear power reactors. The HEU consists of uranium-metal buttons and uranium/aluminum ingots, which are processed and mixed with natural uranium in the BPF. Specifically, the BPF process operations consist of high-enriched Uranium Metal oxidation and dissolution, Uranium/Aluminum (UAl) dissolution, Solvent Extraction, Downblending of highly enriched uranium solution with natural uranium blendstock solution, and Liquid Waste Discard. The natural uranium blendstock solution is prepared by dissolving natural uranium oxide in nitric acid. The overall process flow diagram for the BPF is identified in Figure 3-1.

The process description is made up of six sections (Uranium Metal Processing, Uranium Aluminum Processing, Solvent Extraction, Downblending, Liquid Waste Discard, and Ventilation System) and each is divided into six subsections: Process Description, Criticality Safety, Chemical Safety, Radiological Safety, Fire Safety, and Environmental Safety. The five safety evaluation subsections define the significant hazards and controls involved in the process from the applicable safety perspective. The Chemical and Radiological Safety sections address hazards to the worker while the Environmental Safety section addresses both chemical and radiological hazards to the public.

A summary table is included at the end of each of the six process description sections to summarize the significant hazards and controls involved in the process for each of the five safety disciplines. The controls listed in the summary tables include system design features and safety program controls, in addition to IROFS controls. The IROFS controls are listed in Section 6 and are determined by the consequence analysis and risk assessment documented in Sections 4.2 and 4.3.

3.1 URANIUM-METAL PROCESSING

3.1.1 Process Description

Figure 3-1

Receiving Containers of HE U-Metal Button Pieces

The broken HE U-metal buttons (average 4.5 kg U per button, 5.5 kg U maximum, with 40-80 wt.% ^{235}U) are packaged by BWXT Y-12, LLC personnel into either a 2-button can (4.25-inch diameter by 10.125 inches tall, 11 kg U maximum) or a 1-button can (4.25-inch diameter by 4.875 inches tall, 5.5 kg U maximum). Some cans contain an aluminum foil pouch which holds swarfs (metal chips). Crumpled aluminum foil or stainless steel mesh pads are placed above the U-metal pieces to fill the void space. The cans are shipped inside appropriate packages (e.g. DOT Specification 6M) to NFS from the Y-12 Complex. Each shipping package holds two 2-button containers or a combination of 1-button and 2-button containers. The shipping packages are delivered to the dock on the south side of Building [redacted] NFS unloads the cargo restraint transports (CRTs) into the shipping/receiving vault. Once inside this vault the shipping packages are removed from the CRTs and staged for unloading.

Inside the shipping/receiving vault the shipping packages are unloaded one at a time. Each container is check weighed and taken to the Storage Vault in Building [redacted] This vault is not part of BPF operations and is currently addressed in License SNM-124.

There are two storage racks in the BPF in close proximity to the U-metal processing area. These racks are used for staging of cans of U-metal prior to processing. These racks contain seven positions with 12-inch vertical spacing (minimum) between positions and 24-inch spacing (minimum) between columns.

The U-metal transfer carts have two shelves, with two positions per shelf. The shelves and positions have fixed minimum spacing to allow up to 12 kg per

position. The carts also have fixed spacing from the positions to the edge of the cart.

U Metal Sampling for Material Control and Accountability (MC&A)

The HE U metal pieces are a pure homogeneous U material, therefore, the U and ^{235}U content of the U metal pieces must be determined within 30 days of receipt. When sampling is to be done, cans of HE U metal are taken from the Storage Vault to a U metal sampling enclosure using a wheeled cart. One can is loaded into the enclosure at a time. Inside the U metal sampling enclosure the top is removed from the can and swarfs or prepackaged samples are removed. The shipper may combine samples into a single container to simplify sampling operations. After the samples are removed from the container they are placed in sample bottles and then into a transfer tube and hand delivered to the lab for analysis. The can is then weighed, tampersafed and returned to the Storage Vault using the wheeled cart. The can and removed samples are completely removed from the enclosure prior to loading the next can in the glovebox.

Uranium-Metal Oxidation and Dissolution

Glovebox Interlock Control System

Each glovebox is equipped with 2 interlocked doors controlled by a programmable logic controller (PLC) to limit the material being processed to one container, or batch, at a time (12 kg maximum). Prior to loading the glovebox, the can is weighed on a scale and read into the PLC. If the contents are less than the maximum batch limit, the PLC allows the outer glovebox door to unlatch. The material is then placed in the airlock. The operator then tells the PLC he/she is ready to load the can into the glovebox. The PLC then locks the outer door and unlocks the inner door. The operator may then remove the can from the air lock and load the materials into the furnace. The outer door then remains locked until

the PLC receives a determination from the Rosemount accounting system on the 3-day test columns that the batch has been completely transferred to the 3-day test columns.

Two valves are cycled during the oxidation phase to allow the solid oxide to pass through to the dissolver. There are interlocks that require one valve to be closed at all times. This feature minimizes any vapors passing from the dissolver to the furnace. The dissolver vessel is heated by an electric band heater that is wrapped around it. Hydrogen peroxide is pumped into the dissolver from a metering column during dissolution to prevent excessive NO_x formation. After dissolution is complete, the solution is transferred to the 3-day test columns for MC&A process monitoring measurements.

3-Day Process Monitoring Tests

HE uranyl nitrate is pumped from the dissolvers to a bank of favorable geometry test columns. The three test columns are manifolded together and there are isolation valves on the bottom of each column. The bank of columns holds at least 300 liters (110 liters per column). The bottom 10 feet of the columns are 5-inch Sch. 40 Stainless Pipe, while the upper 10 feet are 6-inch borosilicate glass pipe. A Rosemount system is connected to these columns to measure the density and volume of the solution. The Rosemount system uses nitrogen to determine a pressure difference at different elevations in the columns. The nitrogen supply is provided with fail safe isolation valves that close on loss of supply pressure.

Each column will vent to a nominal 6-inch diameter borosilicate glass knockout column. At the top of each column is a deionized water flush line. The deionized water header has an interlocked valve that closes on loss of supply pressure. A port is provided on the suction side of the recycle/transfer pump to obtain a sample for MC&A monitoring. This port is also used to return samples and purge solution to the columns. The pump recycles the uranyl nitrate solution or transfer the solution to 7-Day Process Monitoring Columns. The pump is sized to properly mix (10 times capacity) the bank of columns in approximately 1.5 hours. Time to pump the solution to the 7-day Process Monitoring Columns is approximately 10 minutes. Separate valves are used to control solution recycle and transfer to 7-Day Process Monitoring Columns.

7-Day Process Monitoring Tests

HE uranyl nitrate will be pumped from the 3-Day Process Monitoring Columns to a bank of 6 storage columns which can be mixed and sampled to meet 7-day testing requirements. The columns are manifolded together and there are isolation valves on the bottom of each column. The bank of columns holds about 600 liters (approximately 110 liters per column). The bottom 10 feet of the columns are 5-inch Sch. 40 Stainless Pipe, while the upper 10 feet are 6-inch borosilicate glass pipe. Each column vents to a safe geometry knockout column. At the top of each

column is a deionized water flush line. The deionized water header has an interlocked valve that closes on loss of supply pressure. A port is provided on the suction side of the recycle/transfer pump to obtain a sample for MC&A monitoring. The pump recycles the uranyl nitrate solution or transfer the solution to HEU Mix/Measure Columns. The pump is sized to properly mix (10 times capacity) the bank of columns in under 2 hours. Time to pump the solution to the HEU Mix/Measure Columns is approximately 20 minutes. Separate valves are used to control solution recycle and transfer to HEU Mix/Measure Columns.

A Rosemount system is connected to these columns to measure the density and volume of the solution. The Rosemount system uses nitrogen to determine a pressure difference at different elevations in the columns.

3.1.2 Hazard Identification and Controls

A summary table of hazards and controls for U Metal Processing is included as Table 3-2.

3.1.2.1 Criticality Hazards and Controls (U Metal Sampling and U Metal Dissolution)

3.1.2.1.1 Uranium Metal Sampling Criticality Hazards

For U metal sampling, uranium metal samples from one can are processed within the sampling glovebox at one time. A single can is opened and pre-existing samples are removed from the can. Up to 21 samples are obtained from individual cans. Each can and the removed samples are removed from the enclosure prior to entry of the next can for sampling. The enclosure has a minimum 1-inch barrier around the inside wall to limit potential reflection from outside the enclosure. Once the samples are placed in the transfer tube, they are delivered to the lab for analysis.

This operation is considered a routine task performed by a trained operator in accordance with an approved procedure. The enclosure is posted with the single can limit identification. It is considered to be highly unlikely that a trained and highly qualified operator would place two additional uranium metal cans (three total) within the enclosure in a close-packed configuration and further modify the enclosure in violation of configuration control requirements to enable full enclosure reflection sufficient to lead to criticality. It is also highly unlikely that a single trained and highly qualified operator would place three additional uranium metal cans (four total) within the enclosure in a close-packed configuration and enable full enclosure reflection sufficient to lead to criticality.

Criticality hazards and controls for U Metal Sampling are summarized in Table 3-2.

3.1.2.1.2 Uranium Metal Dissolution Criticality Hazards

3.1.2.2 Chemical Hazards and Controls – Worker (U Metal Dissolution)

Chemical Inputs or byproducts in the U Metal Dissolution process area or the U Metal Sampling area which have established employee exposure limits or present physical hazards include:

- U metal considered for potential chemical hazards
- Nitric Acid, 67 percent by weight - oxidizer, corrosive
- NO_x emissions
- Nitrogen gas - asphyxiant

- Hydrogen Peroxide, 30 percent by weight - oxidizer, corrosive
- Uranyl Nitrate - oxidizer, corrosive
- Argon gas – asphyxiant
- U_3O_8 – radioactive material

Other inputs include process water and compressed air.

Chemical Reactions:

$3U + 4O_2 \rightarrow U_3O_8$
$U_3O_8 + 6HNO_3 + H_2O_2 \rightarrow 3UO_2(NO_3)_2 + 4H_2O$
**$3NO_2 + H_2O \Leftrightarrow 2HNO_3 + NO$
**$NO + HNO_3 + H_2O \rightarrow 3HNO_2$
**$HNO_2 + H_2O_2 \rightarrow HNO_3 + H_2O$

**These equations relate to the removal of NO_x through the addition of hydrogen peroxide.

Table 3-1 Chemical Hazard Interaction Matrix – U Metal is provided for consideration of U Metal chemical hazards.

Table 3-1
Chemical Hazard Interaction Matrix – U-Metal

Chemical Name	Argon	Comp. Air	Cooling Water	DI Water	Hydrog Perox.	Nitric Acid	Nitrog. (gas)	NO_X vapor	U Metal	Uranyl Nitrate	U_3O_8
Argon	same	none	none	none	none	4	none	none	none	none	none
Compressed Air	[illegible]	same	none	none	none	none	none	none	none	none	none
Cooling Water	[illegible]	[illegible]	same	none	none	4	none	4	none	none	none
DI Water	[illegible]	[illegible]	[illegible]	same	none	4	none	4	none	none	none
Hydrogen Peroxide, 31% (solution)	[illegible]	[illegible]	[illegible]	[illegible]	same	4	none	none	4,6	none	4,6
Nitric Acid, 67% (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4	4	4	4	4,5
Nitrogen (gas)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	none	none	None
NO_X (vapor)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4,6	none	4,6
Uranium Metal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4,6	4,4
Uranyl Nitrate (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4,5
U_3O_8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same

1=Heat generated from chemical reaction may initiate explosion.
2=May cause fire.
3=Flammable gas generation.
4=Heat generation by chemical reaction, may cause pressurization.
5=Can become highly flammable in use; causes pressurization.
6=Contact with substance liberates toxic gas; causes pressurization.
7=Innocuous and nonflammable gas generation; causes pressurization.

Chemical Hazards:

A spill of 67 percent Nitric Acid resulting in a loss of contents of the [redacted] gallon bulk tank would potentially result in an employee exposure above the ERPG-3 level. Unmitigated, this would be classified as a high consequence event. The exact amount of the spill would be dependent on the severity of the line break or leak, or the severity of the valve failure or leak. The amount of the spill would also be dependent on the time until operator intervention. Isolation valves on the bulk nitric acid input lines to the building would prevent a spill through a line break or valve failure when the building was unoccupied. Spring-loaded valves at the use points will serve to ensure operator presence during nitric acid addition. Column overflows would be diverted to a glass ventilation knockout column.

A spill resulting from a line break, column failure, or valve failure at the hydrogen peroxide column in the area would not be expected to result in an employee exposure greater than the established ERPG-2 limit for a limited exposure time, nor would an exposure resulting from nitric acid fumes from process solution spills or NO_x emissions.

A spill resulting from a 2-liter container of hydrogen peroxide would not be expected to result in an employee exposure greater than the established ERPG-2 limit for a limited exposure time.

During normal operations, employee exposure to chemical vapors involved in the dissolution of U Metal are controlled though process exhaust ventilation. In the event of a Uranyl Nitrate spill, employee exposure to nitric acid or NO_x vapors would not be expected to be above the established ERPG-2 limit. A release of nitrogen or argon to the work area would not be expected to create an oxygen deficient atmosphere.

Chemical hazards for U Metal dissolution are summarized in Table 3-2.

Chemical Controls:

It is the policy of NFS to minimize the risk associated with the use and storage of hazardous chemicals, in accordance with federal and state regulations.

Provisions for managing the safe storage and use of hazardous chemicals which are integrated into the processing of radioactive materials or are generated by chemical reaction during processing include the following:

- Chemical evaluation during the design process to identify the hazards associated with the use and storage of hazardous chemicals.
- Administrative control through training and specific instructions contained in approved NFS procedures. This may include specific hazard warnings,

personal protective equipment requirements, and/or spill response instructions.

- Routine audits and assessments as required by approved procedures.
- Engineering controls, as appropriate, for hazardous chemicals which have the potential to impact safety. These may include, but are not limited to, equipment design safety features such as pressure relief valves or interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition to the general controls listed above, the U Metal processing area would rely on utility line elevation design, and isolation valves as engineering controls. Other engineering controls include the glass knockout column and spring-loaded valves on the chemical input lines at the use points.

In the BPF process design, the majority of hazardous chemicals are piped into the process to minimize potential employee contact with the chemical during normal operations. In addition, most hazardous chemicals used in conjunction with radiological materials are handled inside process containment, with any vapors vented into the Wet Process Off-Gas System. Compressed Gas lines utilize pressure regulators, pressure indicators, flow meters, and pressure safety valves at appropriate locations in the line to insure safe operation.

As stated in the NFS Stormwater Pollution Plan, engineering controls for chemicals stored outside in bulk quantities at the NFS plant include secondary containment systems (dike or sump). Dike areas are not provided for compressed gas tanks. Chemical Spill Response Houses stocked with spill response supplies are located in areas where bulk chemicals are stored and/or unloaded.

Emergency Eye Washes and Safety Showers are located in areas where corrosive chemicals are used and are routinely inspected and tested in accordance with applicable NFS procedures.

Chemical controls for U-Metal Dissolution are summarized in Table 3-2.

3.1.2.3 Radiological Hazards and Controls – Worker (U-Metal Dissolution)

The U-Metal Dissolution Process uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the U-Metal Dissolution Process is the loss of containment of the radiological materials being processed. Containment is maintained by materials of construction and verified by the radiological monitoring program.

Radiological Hazards:

The radiological hazards or Material at Risk (MAR) that could potentially be affected by an event in the U-metal dissolution process are summarized in Table 3-2.

The uranium materials are enriched in the isotope ^{235}U and include progeny of the isotopes of uranium as well as other radionuclides. Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the MAR did not meet the criteria for intermediate or high consequences to the worker. The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

The BPF is a Controlled Area, and both engineered and administrative radiation protection controls are utilized in the U-Metal Dissolution Process. Personnel training and approved procedures allow for safe operation and quick detection of any unfavorable trend so that appropriate corrective action can be implemented. The controls afforded by NFS' Radiation Protection Program for BPF operations maintain airborne radioactivity, contamination levels, and radiation levels within specified limits to protect against occupational radiological hazards associated with operations in U-Metal Dissolution. There are no IROFS identified for the U-Metal Dissolution process based on the Radiological Safety Consequence Analysis documented in Section 4.2.

Radiological controls for the U-metal dissolution process are summarized in Table 3-2.

3.1.2.4 Fire and Explosion Hazards and Controls (U-Metal Dissolution)

The U-Metal Dissolution process involves oxidation of HE uranium metal pieces and dissolution with nitric acid to produce high-enriched uranyl nitrate solution (HEUN). There are four potential fire hazards associated with the U-Metal Dissolution process:

Fire Inside a U Metal Glovebox

Uranium metal is stored in metal cans in a broken form categorized as U-metal button pieces. U metal is also received in the form of small bits of the button material that are created during the breaking or shearing process known as swarfs, drilled material, helix shaped metal pieces called turnings, and oxide powder. The swarfs and turnings are leftover sample material not used in the sampling process at NFS or samples held back at the DOE site until the

confirmatory process is completed. The oxide powder was collected at the DOE site during the repackaging of the U-metal.

In the U-Metal process, the container is placed into the enclosure. Once the lid to the container is removed, the U-Metal material is placed into a basket.

The material is oxidized to U_3O_8.

The furnace is vented to the enclosure.

This temperature is not high enough to ignite ordinary combustibles. Additionally, there is no thermal impact to the butyl gloves, Lexan®, HEPA filters or to the plastic CPVC POG line. No other heated gases are expected in the enclosure. There are two enclosures.

Metal

The U-Metal buttons are broken or sheared in a press at a DOE site. The process of breaking/shearing the buttons in a press does not generate dust. The pieces are then placed into a can, on top of a stainless steel mesh pad, which acts as a cushion. The most likely dust generator is pieces rubbing together in the can and abrading each other. Currently, the void spaces in the cans are packed with stainless steel mesh pads, to prevent this abrasion from occurring. Additionally, the can is placed under an inert atmosphere, argon, to prevent combustion through oxygen exclusion.

The U-Metal pieces inside the cans, as well as the swarfs or turnings in the glass vials, have a surface area to mass ratio less than 50 cm^2/g. Based on researched DOE literature, Report# Y/LF-668, Testing of Y-12 Materials for Pyrophoric Properties, dated June 13, 2002, pieces of this size range do not present a pyrophoric fire hazard. Exposure to air pacifies this material in that a thin layer of U_3O_8 is formed on the U-Metal surface. U_3O_8 is the form that is found in nature and, under normal environmental conditions, is stable both from an energy standpoint as well as a reactivity standpoint. U_3O_8 is the highest oxidized state and will not oxidize further. Also, this material has no significant hazardous chemical properties.

If the can is inverted to remove the U-Metal button pieces, swarfs or turnings, the U-Metal may come into momentary contact with each other and sparks may be generated due to frictional heating. These sparks are of short duration, low energy, and low thermal mass. These sparks do not have enough thermal mass or heat output to cause ignition of a larger piece of U-Metal or damage the non-

combustible enclosures, containers, or equipment located in the enclosures. The sparks may cause low-density transient combustibles to ignite.

Low-mil plastic which lines the U-Metal container, the stainless steel mesh pad located in the U-Metal container, and butyl rubber gloves attached to the enclosure, are expected to be in the enclosure. The plastic and the rubber are low-density, combustible materials that may ignite. The plastic will thermally degrade with momentary flaming combustion but the heat output will not compromise the enclosures, containers, or equipment. The stainless steel mesh pad will not sustain combustion.

A burn test was completed on 11/12/03, involving the stainless steel mesh pad with the following results. The stainless steel mesh pad, under propane torch conditions, did not support combustion. The plastic, which is expected in the area, did support combustion when melted into the stainless steel mesh pad. This was a low energy flame as the majority of the plastic melted into globular form. Based on the information above, no ignition is expected to a larger piece of U-Metal and no damage to the non-combustible enclosures or equipment located within the enclosures. The U-Metal turnings may oxidize if exposed to direct flame impingement. The gloves are made of 30-mil butyl rubber. These gloves will ignite if exposed to direct flame impingement.

If the unlikely situation occurs where the uranium-metal turnings oxidize, flaming combustion would not occur. This combustible metal would turn orange, known as glowing combustion, momentarily and self-extinguish. The low heat output would not be expected to damage the enclosures or metal equipment or containers or cause ignition of a larger piece of U-Metal.

Powder

It is expected that U_3O_8 powder will also be received. U_3O_8 is the form that is found in nature and, under normal environmental conditions, is stable both from an energy standpoint as well as a reactive standpoint. U_3O_8 is the highest oxidized state and will not oxidize further. Also, this material has no significant hazardous chemical properties.

A U_3O_8 powder explosion is not anticipated due to the size of powder being produced, the stability of U_3O_8 in the form to be produced, and the density of the U_3O_8.

Furnace Overheating

The general MSDS sheet for uranium metal indicates that uranium will melt at 2,069°F (1,132°C). However, this is somewhat misleading as uranium metal will not melt in the presence of oxygen but will oxidize to U_3O_8. U_3O_8 is the highest

oxidized state and will not oxidize further. U_3O_8 is stable both from an energy standpoint as well as a reactive standpoint and does not present a fire hazard.

The U metal furnace has over-temperature protection, which will automatically shut down the furnace if the temperature reaches 2,012°F (1,100°C). The maximum temperature that the furnace can produce, based upon its power input design, is 2,012°F (1,100°C).

Having an internal furnace fire or internal furnace-overheating situation is highly unlikely based upon the fact that the uranium will be oxidized to U_3O_8, which is thermodynamically stable, and the furnace is equipped with continuous temperature monitoring and high temperature shutdown interlocks.

There are no flammable or combustible gases or liquids used in the U metal process area. The utility pipes in the area consist of nitrogen, nitric acid, plant air, process water, DI water, and cooling water.

The cooling water, deionized water, process water, and plant air systems represent no fire hazard. Nitrogen is a nonflammable gas and has no hazardous decomposition products.

Hydrogen peroxide used in the process is 31%. As per the MSDS sheet for hydrogen peroxide, hydrogen peroxide mixes with water and is nonflammable; however, this chemical is an oxidizer. Hydrogen peroxide in the piping is at ambient temperature. Release from containment should not create a situation where sufficient fumes or vapors are drawn into the furnace to react with the material that is being oxidized in the furnace. If a reaction did occur, potential damage to the furnace enclosure, due to the oxidizer nature of this chemical, may cause localized damage of some furnace components from increased heat output but should not require major repairs. A solution of hydrogen peroxide decomposes slowly, releasing oxygen. Even if the furnace should fail high, the potential of a flammable/combustible gas-type explosion or fire as a result of a hydrogen peroxide release is not credible.

Nitric acid used in the process is 67%. As per the MSDS sheet for nitric acid, nitric acid is soluble in water and nonflammable; however, this chemical is an oxidizer. Nitric acid in the piping is at ambient temperature. Release from containment should not create a situation where sufficient fumes or vapors are drawn into the furnace to react with the material being oxidized in the furnace. If a reaction did occur, potential damage to the furnace enclosure, due to the

oxidizer nature of this chemical, may cause localized damage of some furnace components from increased heat output but should not require major repairs. Nitric acid decomposes upon heating and produces toxic fumes of nitrogen oxides. The potential of a flammable / combustible gas-type explosion or fire as a result of a nitric acid release is not credible.

There is a potential for hot work being conducted in this area. The process will be shut down should acetylene gas cylinders be introduced into this area. This hot work will be administratively controlled by hot work procedures, requiring shutdown of the U metal furnaces if hot work involving flammable gas cylinders is conducted within a defined distance

Excess Temperature Exposing POG Plastic Ducting and HEPA Filter

The exhaust from the U metal dissolver, which is primarily heated air, is connected through stainless steel piping to a demister (where any U_3O_8 noncombustible dust is captured) and through a condenser where the heated exhaust air would be cooled. Downstream of the condenser the clear PVC pipe is connected to the clear PVC WOG line ducting which is connected to a knockout column.

Fire hazards and controls for the U-Metal Dissolution process are summarized in Table 3-2.

The controls listed in Table 3-2 are required by the FHA. Since these controls were not required to prevent exceeding the 10 CFR 70.61 exposure criteria they are not listed in Section 6 as IROFS.

3.1.2.5 Environmental Hazards and Controls – Public (U-Metal Dissolution)

The environmental hazards for the U-Metal Dissolution process are the hazardous chemicals and radiological materials that have the potential for being released outside the BPF resulting in levels above the criteria specified in 10 CFR 70.61 outside the Controlled Area. The levels of concern for environmental hazards defined by 10 CFR 70.61 are defined in Section 7. For the U-Metal Dissolution process, the hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions.

Environmental hazards for the U-Metal Dissolution process are summarized in Table 3-2.

Environmental Controls:

As determined in Section 4.2.5, one Environmental Radiological scenario for the U-Metal Dissolution process was determined to exceed action levels specified in 10 CFR 70.61. All other postulated accident scenarios were determined to be Low consequence events.

Environmental controls for the U-Metal Dissolution process are summarized in Table 3-2.

Table 3-2
Hazard Summary for U-Metal Processing

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	U metal in unsafe geometry container Backflow to unfavorable geometry utility or chemical makeup supplies Container or mass limit exceeded in storage, carts, or Enclosure Transfer of U-Metal to columns Flood Enclosure Pipe leak to unf. geom. Maximum reflection condition exceeded outside enclosure	Favorable geometry metal containers Fixed spacing on storage columns and carts Overflows on columns Favorable geom. equipl Filters Elevation control on utility and chemical supply lines Enclosure reflection control Dbl. sleeve pipe Enclosure overflow drains	Interlocked valves or spring-closed valves on utility and chemical makeup supplies Interlocks, scale, PLC, and Rosemount Bagout door	Only favorable geometry containers allowed in HEU area Enclosure container and mass control Weigh U-Metal containers to verify mass limit prior to storage One hand-carried container per operator and 12" spacing Hydrogen to Uranium H/X ratioVerification that container shipping documents don't exceed mass limits
Chemical	Nitric acid spill (67%) Uranyl nitrate spill NO_x emissions Hydrogen peroxide spill (30%) Nitrogen release to the work area Argon release to the work area	Materials of const. Piping and columns welded const. Knockout column overflows	Addition of Hydrogen peroxide from metering column Utility supply interlocks, isolation valves Emergency eye wash and safety showers Chemical makeup spring loaded valves Spring closed and spring return valves for chemical makeup	Personnel training and Procedures Spill response procedures and supplies Routine audits and inspections

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Radiological	HEUN solution HEU metal/solution U_3O_8	Separation of U-Metal process area	Rad. Prot. Prog. monitoring and instruments	Personnel training and procedures Rad. Prot. Program controls
Fire and Explosion	Fire in U metal glovebox U metal furnace overheating Excess POG exhaust temperature Flammable or combustible vapors	Low fire hazard materials in process area	Overtemperature shutdown controls on heaters and furnaces Temperature monitoring for furnace	Hot work controls including shut down of furnace Enclosure gloves tied off when not in use Class "D" fire ext. agent in area Tweezers/tongs to remove samples from vials
Environmental	Nitric acid spill (67%) HEUN spill Hydrogen Peroxide spill Nitric Oxide release (Operational upset: failure to add H_2O_2) Uranyl Nitrate spill (nitric acid solutions) HE U_3O_8 dispersion HE U metal dispersion	Equip. construc. controls Process exhaust ventilation scrubber HEPA filters Materials of construction	None.	Personnel trng. and qualf. Oper. and Emerg. Procedures

3.2 URANIUM/ALUMINUM ALLOY PROCESSING

3.2.1 Process Description

The main feedstock to the BPF UAl Dissolution Process is HEU in the form of Uranium/Aluminum Alloy. The uranium has an average enrichment of 65.5 wt.% in the ^{235}U isotope, and is in the form of cylindrical ingots having average UAl mass of 5 kg (maximum 6.88 kg UAl, average 0.93 kg U/ingot, max 2.6 kg U/ingot). The UAl is transported to the dissolution area in 4 ¼-inch diameter by 10 1/8-inch high metal cans. The UAl Dissolution process consists of six stages: BPF storage of UAl containers, caustic chemical makeup and storage, UAl dissolution, UAl separation, UAl caustic discard, and UAl accountability.

Storing Inner Containers of UAl Ingots

Upon receipt, the containers of HE UAl ingots will be stored in a high security storage area (HSSA) on the mezzanine level of the BPF. A lift will be available to move the material containers to the second floor storage area.

Caustic Chemical Makeup and Storage

Uranium/Aluminum Dissolution

Uranium/Aluminum Separation

Uranium/Aluminum Accountability Columns

The UN solution, produced in the UAl separation area dissolvers, is directed to the UAl accountability columns. The three accountability columns, located in the BPF column storage area, have a capacity of 110 liters. The bottom 10 feet of the column is 5-inch Sch. 40 pipe and the upper 10 feet is 6-inch borosilicate glass pipe. Before reaching the accountability columns, the UN solution passes through an enclosure, which contains two cartridge filters arranged in series. The cartridge filters remove any solids suspended in the UN solution. The UN solution enters one of the columns and is re-circulated among the three accountability columns.

After the UN solution is homogeneously mixed among the accountability columns, it is sampled to ensure it meets the criteria for transfer to the solvent extraction area. This sample is also the first point of accountability for receipt of the material.

Caustic Discard Solution Measurements

Caustic discards will be fed from the centrifuges into a single column in one of the two banks of stainless steel columns. The columns will be manifolded on both top and bottom, with isolation valves on the bottom of each column. The two banks of columns are sized to hold approximately 800 liters each, with eight columns per bank. Each column is a 5-inch diameter by 25-foot tall stainless steel pipe. Each

column will vent to a caustic knockout column. At the top of each column is a deionized water flush line. Each water flush line will have an isolation valve. A port is provided on the suction side of the recycle/transfer pump to obtain a sample for release to unfavorable geometry equipment and MC&A monitoring. This port will also be used to return samples and purge solution to the columns.

The pump will recycle the caustic solution or transfer the solution to the liquid waste discard tank. The pump is sized to properly mix (10 times capacity) the discard columns in approximately 1.5 hours. Time to pump the solution to the discard tank will be approximately 10 minutes. Separate valves are used to control solution recycle and transfer to the caustic discard tank. Hazards and controls associated with transfer to the liquid discard tanks are addressed in Section 3.5.

3.2.2 Hazard Identification and Controls (UAl Dissolution)

A summary table of hazards and controls for UAl Dissolution is included as Table 3-4.

3.2.2.1 Criticality Hazards and Controls (UAl Dissolution)

Storage Area and Transfer Cart

The UAl storage racks and transfer carts are designed with fixed spacing and fixed positions. The primary hazards would involve placement of additional containers of fissile material next to the racks, or more than the expected mass of U in fixed positions. Administrative controls and operator training are provided to ensure that containers are only placed in fixed positions, and hand-carried items as well as carts are limited to control interactions with other fissile material. The cart and rack analyses evaluate up to 7 kg U per container. This is conservative considering that the maximum expected UAl mass is 6.88 kg, with a maximum of 40 wt.% U. Administrative controls are also provided to verify container mass prior to storage in the racks.

UAl Dissolution

The dissolvers, centrifuges, and columns in the UAl Dissolution area can contain highly enriched uranium mixtures, however, this equipment is designed with favorable geometry. The equipment is also spaced to prevent appreciable neutron interaction.

The primary nuclear criticality hazards in the UAl Dissolution Area arise from process upsets. The main upsets of concern are process control failures that lead to equipment overflows with potential to backflow into unfavorable geometry utility supply systems (deionized water, plant air, nitrogen, bulk nitric acid, chemical make-up, and cooling water). The utility supplies are installed at an elevation higher than the WOG line, providing a passive barrier that relies only on

the laws of physics to prevent backflow scenarios from propagating. The WOG line flows to the knockout column which overflows to the floor. In addition, engineered controls, including passive overflows and interlocked supply valves, are in place to prevent backflow if the passive barriers are overcome.

The passive overflows require geometric control for the potential criticality hazard of spilling highly enriched uranium mixtures to the floor. The UAl Dissolution Area floor is engineered to be essentially flat, and dikes are in place as passive engineered controls to contain highly enriched uranium mixtures in a safe slab geometry. In fact, the floor area is large enough to contain the entire UAl Dissolution Area uranium inventory to a safe slab height.

Handling fissile material in containers presents another potential criticality hazard in the UAl Dissolution Area. The UAl dissolver enclosure has a single container limit and a single container mass limit of 7 kg. The dissolver has a 28 kg (4 ingots) UAl mass limit. The enclosure air lock chamber is equipped with two magnetically locked doors that are controlled by a programmable logic controller (PLC). The PLC interfaces with a scale, and the enclosure air lock chamber door, to prevent material addition to the dissolver once the mass limit has been reached. Passive reflection control is provided by the enclosure design. The wall of the enclosures are designed with a barrier to provide reflection control to ensure that a maximum upset involving four UAl containers (limit is one) will be maintained subcritical, regardless of configuration.

The transfer of highly enriched uranium mixtures to an unfavorable geometry container during a catastrophic release (equipment or process line rupture) presents another potential criticality hazard in the UAl Dissolution Area. Unfavorable geometry containers are restricted from the BPF to prevent a potential criticality. In addition, operator training and area procedures direct the use of 2-liter bottles, or smaller, for fissile material handling.

Criticality hazards and controls for the UAl Dissolution process are summarized in Table 3-4.

3.2.2.2 Chemical Hazards and Controls – Worker (UAl Dissolution)

Chemical Inputs or byproducts in the Uranium/Aluminum Dissolution process area which have established employee exposure limits or present physical hazards include:

- Uranium/Aluminum Alloy - radioactive material
- Nitric Acid, 67 percent by weight - oxidizer, corrosive
- Ammonia emissions
- Hydrogen emissions
- Nitrogen gas - asphyxiant
- Sodium Diuranate

- Sodium Hydroxide - corrosive
- Sodium Nitrate
- Sodium Nitrite
- Barium Nitrate
- Barium Carbonate
- Sodium Aluminate
- Uranyl Nitrate - oxidizer, corrosive
- Uranium Dioxide

Other inputs include process water, deionized water and compressed air.

Chemical Reactions:

$8Al + 5NaOH + 3\ NaNO_3 + 2H_2O \rightarrow 8NaAlO_2 + 3NH_3$

$2Al + 2NaOH + 3NaNO_3 \rightarrow 2NaAlO_2 + H_2O + 3NaNO_2$

$20Al + 17NaOH + 21NaNO_3 \rightarrow 20NaAlO_2 + 18NaNO_2 + 3NH_3 + 4H_2O$

$2U + 2NaOH + 5\ H_2O \rightarrow Na_2U_2O_7 + 6H_2$

$Na_2U_2O_7 + 6HNO_3 \rightarrow 2UO_2(NO_3)_2 + 2NaNO_3 + 3H_2O$

$Ba(NO_3)_2 + CO_3^{-2} \rightarrow BaCO_3 + 2NO_3$

Bulk nitric acid concentration = 67% by weight
Bulk Sodium Hydroxide concentration = 30% by weight

Table 3-3 (Chemical Hazards Interaction Matrix – UAL) is provided for consideration of UAl chemical hazards.

Table 3-3
Chemical Hazard Interaction Matrix - UAl

Chemical Name	Ammonia	Bar. Carb.	Barium Nitrate	Comp. Air	Cooling Water	DI Water	Hydrog	Nitric Acid	Nitrog. (gas)	NO_x vapor	Sod. Alum.	Sod. Hydrox	Sod. Nitrite	Sod. Nitrate	Uranyl Nitrate	Sodi Diur	Urani Alum	Urani Diox
Ammonia	same	4	4,6	none	none	none	4	2,4	none	4,6	none	none	4,6	4,6	3,4,8	4	4	4
Barium Carbonate	[illegible]	same	4,6	none	none	none	4	1,2,3,4,6	none	4,6	4	4	4,6	4,6	4,6	4	4	4
Barium Nitrate	[illegible]	[illegible]	same	none	none	none	1,2,4	4	none	none	4,6	4,6	none	none	none	4,6	4,6	4,6
Compressed Air	[illegible]	[illegible]	[illegible]	same	none	none	none	none	none	none	none	none	none	none	none	none	none	none
Cooling Water	[illegible]	[illegible]	[illegible]	[illegible]	same	none	none	4	none	4	none	4	none	none	none	none	none	none
DI Water	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	4	none	4	none	4	none	none	none	none	none	none
Hydrogen	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	9,10,3,4,5	none	4,6	4	4	1,2,4	1,2,4	none	none	none	none
Nitric Acid, 67% (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4	4	2,4	2,4	4	4	4	4,5	4,5	4,5
Nitrogen (gas)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	none	none	none	none	none	none	none	none
NO_x (vapor)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4,6	4,6	none	none	none	4,6	4,6	4,6
Sodium Aluminate (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	4,6	4,6	4,6	4	4	4
Sodium Hydroxide, 30% (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4,6	4,6	4,6	4	4	4
Sodium Nitrite (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	none	4,6	4,6	4,6
Sodium Nitrate, 45% (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	4,6	4,6	4,6
Uranyl Nitrate (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4,6	4,6	4,6
Sodium Diuranate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4	none
Uranium/Aluminum	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none
Uranium Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same

1=Heat generated from chemical reaction may initiate explosion.
2=May cause fire.
3=Flammable gas generation.
4=Heat generation by chemical reaction, may cause pressurization.
5=Can become highly flammable in use; causes pressurization.
6=Contact with substance liberates toxic gas; causes pressurization.
7=Innocuous and nonflammable gas generation; causes pressurization.
8=Explosive due to vigorous reaction or reaction products may produce detonation
9=Explosive when mixed with oxidizing substances
10=Fire from exothermic reaction-ignition of products or reactants

Chemical Hazards:

A spill of 67 percent Nitric Acid resulting in a loss of contents of the [redacted] gallon bulk tank would potentially result in an employee exposure above the ERPG-3 level. Unmitigated, this would be classified as a high consequence event. The exact amount of the spill would be dependent on the severity of the line break or leak, or the severity of the valve failure or leak. The amount of the spill would also be dependent on the time until operator intervention. Isolation valves on the bulk nitric acid input lines to the building would prevent a spill through a line break or valve failure when the building was unoccupied. Spring-loaded valves at the use points will serve to ensure operator presence during nitric acid addition. Column overflows would be diverted to a glass ventilation knockout column. A spill resulting from a column failure or valve failure at the nitric acid column in the area would not be expected to result in an employee exposure greater than the established ERPG-2 limit for a limited exposure time.

A spill of caustic solution would not be expected to result in a significant exposure. Although sodium hydroxide has an established ERPG limit and sodium nitrate, sodium nitrite, sodium aluminate, and barium compounds have established TEEL levels, these levels were established for the solid chemical form. As a solution, any vaporization would be expected to consist primarily of water vapor, with little or no chemical components.

Calculations were performed assuming a mode of force that would result in an airborne release of dissolved solids. An overflow of Tank 1K02 from the Sodium Hydroxide Bulk Tank, a line break or a tank failure of Tank 1K02, assuming a one centimeter spill depth in the dike discard area, would result in an intermediate consequence level event. A breach of the tanker delivering sodium nitrate/barium nitrate solution, a line break, an overflow of Tank 1K01 or a tank failure of Tank 1K01, assuming a one centimeter spill depth in the dike discard area, would result in an intermediate consequence event. A process upset in the Caustic Make-Up and Storage Tanks could result in an increase or build up of gases in the Uranium/Aluminum area. A potential explosion in the Uranium/Aluminum area was evaluated in the Dissolution scenarios and would be classified as an intermediate level event.

During normal operations, employee exposure to chemical vapors involved in the dissolution of Uranium/Aluminum are controlled though process exhaust ventilation. In the event of a Uranyl Nitrate spill, employee exposure to nitric acid, ammonia, hydrogen or NO_x emissions would not be expected to be above the established ERPG-2 or TEEL-2 limit. A release of nitrogen to the work area would not be expected to create an oxygen deficient atmosphere.

Chemical hazards for the UAl Dissolution process are summarized in Table 3-4.

Chemical Controls:

It is the policy of NFS to minimize the risk associated with the use and storage of hazardous chemicals, in accordance with federal and state regulations.

Provisions for managing the safe storage and use of hazardous chemicals which are integrated into the processing of radioactive materials or are generated by chemical reaction during processing include the following:

- Chemical evaluation during the design process to identify the hazards associated with the use and storage of hazardous chemicals.
- Administrative control through training and specific instructions contained in approved NFS procedures. This may include specific hazard warnings, personal protective equipment requirements, and/or spill response instructions.
- Routine audits and assessments as required by approved procedures.
- Engineering controls, as appropriate, for hazardous chemicals which have the potential to impact safety. These may include, but are not limited to, equipment design safety features such as pressure relief valves or interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition to the general controls listed above, the Uranium/Aluminum processing area would rely on supply line isolation valves as engineering controls. Other engineering controls include the glass knockout column, compatible materials of construction, welded piping on the nitric acid input lines and spring-loaded valves on the chemical input lines at the use points.

In the BPF process design, the majority of hazardous chemicals are piped into the process to minimize potential employee contact with the chemical during normal operations. In addition, most hazardous chemicals used in conjunction with radiological materials are handled inside process containment, with any vapors vented into the Wet Process Off-Gas System. Compressed Gas lines utilize pressure regulators, pressure indicators, flow meters, and pressure safety valves at appropriate locations in the line to insure safe operation.

As stated in the NFS Stormwater Pollution Plan, engineering controls for chemicals stored outside in bulk quantities at the NFS plant include secondary containment systems (dike or sump). Dike areas are not provided for compressed gas tanks. Chemical Spill Response Houses stocked with spill response supplies are located in areas where bulk chemicals are stored and/or unloaded.

Emergency Eye Washes and Safety Showers are located in areas where corrosive chemicals are used and are routinely inspected and tested in accordance with applicable NFS procedures.

Chemical controls for the UAl Dissolution process are summarized in Table 3-4.

3.2.2.3 Radiological Hazards and Controls – Worker (UAl Dissolution)

The UAl Dissolution process uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the UAl Dissolution process is the loss of containment of the radiological materials being processed. Containment is maintained by materials of construction and verified by the radiological monitoring program.

Radiological Hazards:

The radiological hazards or Material at Risk (MAR) that could potentially be affected by an event in the uranium aluminum alloy dissolution process are summarized in Table 3-4.

The uranium materials are enriched in the isotope ^{235}U and include progeny of the isotopes of uranium as well as other radionuclides. Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the MAR did not meet the criteria for intermediate or high consequences to the worker. The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects, shock effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

The BPF is a Controlled Area and Engineered as well as administrative radiation protection controls are utilized in the Uranium Aluminum Alloy Dissolution Process. Personnel training and approved procedures are used to allow for safe operation and quick detection of any unfavorable trend so that appropriate corrective action can be implemented. The controls afforded by NFS' Radiation Protection Program for BPF maintain airborne radioactivity, contamination levels, and radiation levels within specified limits to protect against occupational radiological hazards associated with operations in Uranium Aluminum Alloy Dissolution. There are no IROFS identified for the UAl process based on the Radiological Safety Consequence Analysis in Section 4.2; however, the hydrogen explosion controls identified in Table 3-4 also provide protection for radiological consequences.

Radiological controls for the UAl Dissolution process are summarized in Table 3-4.

3.2.2.4 Fire and Explosion Hazards and Controls (UAl Dissolution)

There are three significant hazard potentials associated with the U-aluminum dissolution process:

Fire or Explosion Inside the Glovebox Enclosure

Hydrogen is produced as an off-gas of the U-Aluminum dissolution process. The hydrogen gas generated averages 2 cfm over eight hours; the maximum hydrogen gas evolution is 4 cfm per dissolver. There are four dissolvers. This hydrogen gas is removed out of the dissolver through a vent line system and air dilution ventilation ducting, located on the roof, which maintain the evolved hydrogen at less than 25% of the LEL at all times. Ammonia will also be generated from this process and will be vented through the same system.

A glovebox enclosure is attached to the top of each dissolver. In order to open the top of the dissolver within the glovebox, a flexible steel braided connection is installed between the top lid of the dissolver and the fixed stainless steel hydrogen vent line which runs from the glovebox to the roof. Prior to charging the dissolver, the dissolver is nitrogen purged.

If a failure occurred at the flexible connection following dissolver operation, hydrogen could be released inside the glovebox enclosure. If the hydrogen ignited at the point of release from static energy, a small flame jet could occur. If unignited hydrogen was released inside the glovebox, it would be released at a low rate (2-4 cfm, not under pressure) and would be exhausted through the glovebox POG ventilation line (at approximately 100 cfm). Should a release occur and the POG line become plugged, then hydrogen could reach LEL (4% by volume in air) inside the glovebox enclosure and, if ignited, could create a flash fire and potential overpressure incident.

Another scenario which could possibly cause a release inside the glovebox enclosure would be plugging of the hydrogen vent line, creating pressure and leakage at the top of the dissolver.

A gas analyzer and detection system monitor hydrogen in the POG glovebox ventilation line connected to the top of the glovebox. At 25% LEL of hydrogen, an alarm sounds, at 50% LEL an interlock shuts down the caustic feed to the dissolver (stops hydrogen generation) and automatically initiate a nitrogen purge of the system.

The gas detection alarms are tied into the fire alarm panel and loss of power to the nitrogen inerting system is monitored.

Flash Fire or Explosion Inside the Hydrogen Off-Gas Exhaust Ventilation System

Hydrogen off-gas along with ammonia, at approximately 100-150°F, are vented from each dissolver through separate vent line systems. The system includes an inline demister and condenser to remove moisture and condensate from the off-gas stream. Following the condenser, hydrogen continues to be vented through stainless steel piping, which is connected to a 14-inch air-dilution ventilation exhaust duct located outside on the building roof. The 14-inch air-dilution ventilation duct is made of stainless steel. A HEPA filtering system and exhaust stack will also be located on the roof. UL 900 pre-filters and UL 586 HEPA filters will be installed.

The hydrogen vent line system is nitrogen purged prior to dissolver startup to eliminate any air pockets in the condenser, demister, and vent line system. If the ventilation exhaust blower fails or the filters become plugged, hydrogen gas is vented to atmosphere through the fresh air inlet.

If air flow is reduced due to plugging at the fresh air inlet, hydrogen gas could accumulate in the ventilation exhaust ducting system on the roof. If ignited, a flash fire with resulting overpressure could occur, damaging the ventilation system equipment and possibly causing minor structural damage to the metal deck roof. Plugging of the 14-inch air-inlet duct is considered highly unlikely.

Blower fan operation and continuous air flow monitoring will be provided with interlocks to shut down the caustic feed to all dissolvers (stops hydrogen generation) and automatically initiate a nitrogen purge through the hydrogen vent line system.

Hydrogen Accumulation at the Ceiling Level

Failure of the hydrogen off-gas vent line system inside the building could release H_2 into the building area, allowing H_2 to accumulate at the ceiling level.

The possibility of having a hydrogen release accumulate inside the building that reaches LEL is very remote. The maximum hydrogen release from one dissolver unit would be 4 cfm (gas is not under pressure, temperature would be approximately 150-200°F). If 4 cfm was released into the building, the chances of hydrogen gas buildup in any one area are remote. The HEU building volume is

approximately 150,000 cubic feet and the area exhaust rate is 22,600 cfm. HVAC system recirculated air flows in the area provide at least 16 air changes per hour. Even if a common cause failure created a situation where a maximum 16 cfm of hydrogen was released into the building, the possibility of accumulating a pocket of H_2 at the ceiling level which could reach LEL and pose a flash fire or explosion potential would be very remote.

From the UAl glovebox, located at the top of the dissolver, a stainless steel vent line is used to exhaust process generated H_2 to the air-dilution duct system separate from the main stack. A demister and condenser unit is installed in the vent line. The H_2 exhausts due to buoyancy and it is not under pressure. The H_2 gas temperature leaving the dissolver would be in the range of 150-200°F and leaving the condenser would be in the range of 80-90°F.

During the beginning of the UAl dissolution process, maximum H_2 generation is 4 cfm. Over the 8-hour process cycle, average H_2 generation is 2 cfm.

If a mechanical failure occurred at a connection point to the hydrogen vent line (i.e., demister, condenser connections), then a possibility exists that a small fraction of the buoyant rising H_2 gas could be released into the building area. A conservative leakage rate would be an assumed release involving 50% of the maximum H_2 generation rate or 2 cfm.

Based on a detailed analysis documented in the FHA, mechanical failure of the H_2 vent line on any one UAl dissolution unit, it is not possible to reach hydrogen LEL (lower explosive limit for H_2 is 4%) in the HEU Process Area.

Inside the building the vent lines are totally separate and independent. To have an explosion, H_2 needs to reach the LEL, which is 4% by volume in air and needs to be ignited.

Based on analysis presented in the FHA, it would take simultaneous vent line failures on three UAl dissolution units to generate sufficient H_2 gas over an 8-hour period to reach an LEL level. (Note: this assumes building exhaust ventilation is not operating). The likelihood of this type of occurrence is considered not credible.

<u>Other Uranium/Aluminum Fire Issues</u>

UO_2

There is a potential for fire due to pyrophoric dry UO_2 formation in the centrifuge. Uranium dioxide (UO_2) slurry may be produced as an intermediate product of the dissolution process. This occurs after the sodium hydroxide trickles over the U-Aluminum ingots and UO_2 or sodium diuranate ($Na_2U_2O_7$) forms inside the dissolver. In the centrifuge, the sodium hydroxide is removed leaving wet solids.

Once the centrifuge fills with wet solids then nitric acid is used in the centrifuge to dissolve the UO_2 or sodium diuranate ($Na_2U_2O_7$) wet solids to form uranyl nitrate. If UO_2 were to be formed in the centrifuge it would be as a damp cake with no mechanism for totally drying the material.

Based on operations input from DOE's Y-12 National Security Complex in Oak Ridge, Tennessee, the UO_2 will not burn as diuranate in a slurry solution. According to Y-12 Complex data, the material is stable even after the water has evaporated and solids are left. Based on operations experience, cloths used to absorb spills and leaks did not combust even after being allowed to dry.

Based on this evaluation, a UO_2 fire scenario is deemed not credible as the material, in wet slurry form, will not burn.

Fire hazards and controls for the UAl Dissolution process are summarized in Table 3-4.

3.2.2.5 Environmental Hazards and Controls – Public (UAl Dissolution)

The environmental hazards for the UAl alloy dissolution process are the hazardous chemicals and radiological materials that have the potential for being released outside the protected area of the site at levels above the criteria specified in 10 CFR 70.61. The levels of concern for environmental hazards defined by 10 CFR 70.61 are defined in Section 7. For the UAl alloy dissolution process, the hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions.

Environmental hazards for the UAl Dissolution process are summarized in Table 3-4.

Environmental Controls:

One spill scenario and one hydrogen explosion scenario were determined to have the potential to result in intermediate environmental consequences. The other environmental consequences evaluated for the UAl dissolution process do not exceed action levels specified in 10 CFR 70.61 and are considered low consequence events. The following environmental safety program controls reduce potential impacts to the environment.

Environmental controls for the UAl Dissolution process are summarized in Table 3-4.

Table 3-4
Hazard Summary for Uranium/Aluminum Alloy Dissolution Process

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	More than 7 kg of fissile material in a position Additional containers next to cart or storage positions Backflow to unfav. geometry utility systems HEUN spill to floor More than 28 kg U in enclosure HEUN spill to unfav. geometry container U metal rather than UAl enters dissolver	Tubing adjacent to columns must be < 2 inches collective diameter Drip pans must be safe slab geometry Fixed positions and fixed spacings on carts and racks Favorable geometry columns and equipment Column and equipment spacing Passive overflows on columns and knockouts UAl dissol. area floor safe geometry 2 overflow drains for each enclosure Reflection control inside enclosures Elevation requirements for WOG and utility lines Redundant overflow drains in each UAl centrifuge and UAl filter enclosure	Isolation valves for chemical makeup supply lines Loss of pressure interlocks on utility supplies Mass and container PLC and interlock control system for enclosures and dissolver Spring-closed isolation valves for nitric acid supply	Mass limit for UAl containers in HSSA Verify less than 7 kg per UAl container Hand carry, spacing, and cart limits in storage and dissolution areas Control on containers allowed in enclosures, including lid and attendance requirements Only favorable geometry containers allowed in HEU area 2-liter limit on containers in UAl dissolution area

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Chemical	Nitric acid spill (67%) Hydrogen generation Ammonia release Caustic solution spill Uranyl nitrate spill Nitrogen release to the work area Sodium diuranate release NO_x emissions Uranium dioxide release	Materials of construction Knockout column overflows Dike containment on chemical makeup Caustic makeup and sodium nitrate tank overflow	Nitrogen purge to dissolvers Separate dilution ventilation system Utility and chemical supply interlocks and isolation valves Spring return valves Emergency eye wash and safety showers	Personnel training and procedures Routine audits and assessments Spill response procedures and supplies Shut upstream isolation valves for nitric acid supply Personnel training on unloading sodium nitrate tanker
Radiological	HEUN solution UAl centrifuge feed ($UO_2/Na_2U_2O_7$) Caustic waste solution UAl ingots Hydrogen explosion equipment damage	Separation of UAl process area	Rad. Prot. Prog. monitoring and instrument	Personnel training and procedures Rad. Prot. Program controls
Fire and Explosion	Fire or explosion in UAl glovebox Fire or explosion in ventilation system Hydrogen accumulation at ceiling level	Low fire hazard materials installed in process areas	Overtemperature shutdown on caustic heater Separate dilution ventilation system Hydrogen monitors and interlocks to caustic feed, sodium nitrate, and nitrogen purge Caustic and sodium nitrate isolation to dissolvers Nitrogen purge on dissolvers	Electrical inside dissolvers; H_2 vent line and exhaust vent duct should be rated as Class 1, Div. 2 Wiring conform with NFPA 70 *National Electric Code®*

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Environmental	Nitric acid (67%) spill Overflow uranyl nitrate solution (nitric acid solutions) Sodium hydroxide, sodium nitrate, barium nitrate, solution spill Ammonia vapor release Nitric oxide vapor release UAI glovebox enclosure hydrogen explosion (potential nitric acid spill) UAI failure to purge hydrogen explosion (potential nitric acid spill)	Materials of construction Dike containment structures Sodium nitrate tanker design certification	Process interlocks Process exhaust ventilation scrubber HEPA filters Fire safety hydrogen controls	Personnel training and procedures Vendor training on unloading sodium nitrate tanker

3.3 SOLVENT EXTRACTION PROCESS

3.3.1 Process Description

The purpose of the BPF SX process is to purify impure uranyl nitrate from the UAl dissolution process. The SX process includes the following operations: extraction, evaporation, solvent recovery, chemical makeup, raffinate storage, and purified product storage (Figure 3-1). Purification is accomplished in two-pass, counter-current, pulsed columns with a solvent specific for uranium. All process columns in the SX process are made of borosilicate glass and stainless steel, with the chemical makeup tanks made from high density polyethylene or stainless steel. The process is conducted using traditional PUREX solvent extraction methods.

The discard liquid streams from the SX process are raffinate and evaporator condensate. The condensate will be collected and measured for SNM content prior to discharge to the WWTF. Raffinate also will be collected and measured for SNM content prior to being transferred for treatment.

Ventilation for SX is provided by the process off-gas (POG) system for dry systems, and a wet off-gas (WOG) system for venting liquid vessels. SX mainly uses a WOG system for column fume control, which also serves as the column overflow control system. The WOG line overflows to a knockout column, which overflows to the floor.

The impure uranyl nitrate solution fed to the SX process is typically between 200 and 300 g U/liter. The SX process consists of 11 distinct subsystems including: First pass solvent extraction, first pass evaporation, second pass solvent extraction, second pass evaporation and storage, first pass solvent wash, second pass solvent wash, interface solids filtering, chemical makeup, first pass raffinate storage, second pass raffinate storage, and condensate collection. The purified UN solution from SX will be concentrated to approximately 285 g U/liter for subsequent transfer to favorable geometry product columns, as feed to Downblending operations.

High-Enriched UN Staging Columns

HEUN is transferred to the SX Staging Columns from the UAl dissolution Accountability columns. The purpose of these columns is to serve as a central collection point for impure uranyl nitrate (UN) solutions that will be processed in the solvent extraction system. Deionized water and nitric acid may be added to the solutions to adjust the solutions to the proper gram U per liter and acid molarity for efficient solvent extraction. Deionized water is also used to rinse the columns at inventory cleanout. The staging column system consists of:

- Two SX staging columns, borosilicate glass (130 liters, 6-inch diameter x 26 feet high)
- Centrifugal pump for mixing and recirculation
- Metering pump for transfer to 1st or 2nd pass extraction

Solvent Extraction

-

Solvent Wash Systems

-

Discard Filtering

SX Evaporator

Condensate Columns

Final Product Storage Columns

Two sets of columns will be provided to collect the uranyl nitrate solution transferred from the 2nd pass concentrate hold column. One set will be filling while the other will be mixed, sampled, and await release by MC&A and QC.

Chemical Makeup Area

3.3.2 Hazard Identification and Controls (Solvent Extraction)

A summary table of hazards and controls for Solvent Extraction is included as Table 3-6.

3.3.2.1 Criticality Hazards and Controls

The columns, piping, and equipment in the SX process are designed with favorable geometry and spacing to prevent interaction. The primary nuclear criticality hazards in the Solvent Extraction Area arise from process upsets. The main upsets of concern are process control failures that lead to column overflows, with potential to backflow into unfavorable geometry utility supply systems (deionized water, plant air, nitrogen, bulk nitric acid, chemical make-up, and cooling water). Passive barriers that rely only on the laws of physics (i.e., elevation), are installed to prevent the backflow scenarios from propagating. In addition, engineered controls, including passive overflows and interlocked supply valves, are in place to prevent backflow if the passive barriers are overcome.

The column overflows require geometric control of area floors due to the potential criticality hazard of spilling HEUN solution to the floor. The Solvent Extraction Area floor is engineered to be essentially flat, and dikes are in place as passive engineered controls to contain HEUN solution in a safe slab geometry. In fact, the floor area is large enough to contain the entire uranium solution inventory in the solvent extraction columns to a safe slab height.

Handling fissile material in containers presents another potential criticality hazard in the Solvent Extraction Area. The impurity layer that forms between the organic and aqueous phases in the solvent extraction process is normally collected in 2-liter bottles and transferred to an enclosure for filtration and recovery of uranium. The enclosure is limited, administratively, to one 2-liter bottle. Passive reflection control is provided by the enclosure design. The reflection control ensures three 2-liter bottles will be maintained subcritical, regardless of configuration, or fissile material concentration.

The transfer of HEUN solution to an unfavorable geometry container during a catastrophic release (process line leak) presents another potential criticality hazard in the Solvent Extraction Area. Unfavorable geometry containers are restricted from Building 333 to prevent a potential criticality. In addition, operator training

and area procedures direct the use of 2-liter bottles, or geometrically safe drip pans, for fissile material handling or leaks.

Criticality hazards and controls for Solvent Extraction are summarized in Table 3-6.

3.3.2.2 Chemical Hazards and Controls – Worker (Solvent Extraction)

Chemical Inputs or byproducts in the Solvent Extraction area which have established employee exposure limits or present physical hazards include:

- Uranyl Nitrate - radioactive material, corrosive, oxidizer
- Nitric Acid, 67 percent by weight - oxidizer, corrosive
- Norpar-12
- Tributyl Phosphate
- Sodium Carbonate
- Nitrogen gas - asphyxiant

Other inputs include process water, deionized water and compressed air.

Chemical Reactions:

Table 3-5 (Chemical Hazard Interaction Matrix – Solvent Extraction) is provided for consideration of Solvent Extraction chemical hazards.

Table 3-5
Chemical Hazard Interaction Matrix - Solvent Extraction

Chemical Name	Comp. Air	Cooling Water	DI Water	Norpar-12	Nitric Acid	Nitrog. (gas)	NO_x vapor	Tributyl Phos.	Uranyl Nitrate	Sod. Carb.
Compressed Air	same	none	none	none	none	none	none	none	none	none
Cooling Water	[illegible]	same	none	none	4	none	4	none	none	none
DI Water	[illegible]	[illegible]	same	none	4	none	4	none	none	none
Norpar-12	[illegible]	[illegible]	[illegible]	same	2,4,7	none	2,4	none	2,4	none
Nitric Acid, 67% (solution)	[illegible]	[illegible]	[illegible]	[illegible]	same	4	4	4,5,6	4	1,2,3,6,4
Nitrogen (gas)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	none	none	none
NO_x (vapor)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	3,4,5,6	none	4,6
Tributyl Phosphate (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	3,4,5,6	none
Uranyl Nitrate (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	4,6
Sodium Carbonate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same

1=Heat generated from chemical reaction may initiate explosion.
2=May cause fire.
3=Flammable gas generation.
4=Heat generation by chemical reaction, may cause pressurization.
5=Can become highly flammable in use; causes pressurization.
6=Contact with substance liberates toxic gas; causes pressurization.
7=Innocuous and nonflammable gas generation; causes pressurization.

Chemical Hazards

A spill of 67 percent Nitric Acid resulting in a loss of contents of the [redacted] gallon bulk tank would potentially result in an employee exposure above the ERPG-3 level. Unmitigated, this would be classified as a high consequence event. The exact amount of the spill would be dependent on the severity of the line break or leak, or the severity of the valve failure or leak. The amount of the spill would also be dependent on the time until operator intervention. Isolation valves on the bulk nitric acid input lines to the building would prevent a spill through a line break or valve failure when the building was unoccupied. A spill of 67 percent Nitric Acid from the 5-gallon nitric acid column in the chemical make up area would not be expected to result in an employee exposure above the ERPG-2 level. Spills of dilute nitric acid would not be expected to result in an employee exposure above the established ERPG-2 for Nitric Acid.

Red oil explosion assumed as a high consequence based on inherent severity of an incident.

Assuming contents of the process as bounding, a spill of Norpar-12, tributyl phosphate, or a mixture would not be expected to result in an employee exposure above the established TEEL-2.

During normal operations, employee exposure to chemical vapors involved in the Solvent Extraction process are controlled though process exhaust ventilation. In the event of a Uranyl Nitrate spill, employee exposure to nitric acid would not be expected to be above the established ERPG-2 limit.

A release of nitrogen to the work area would not be expected to create an oxygen deficient atmosphere for a limited exposure time. A spill of 5 percent sodium carbonate solution would not be expected to result in an employee exposure greater than the TEEL-2 limit.

Chemical hazards for Solvent Extraction are summarized in Table 3-6.

Chemical Controls:

It is the policy of NFS to minimize the risk associated with the use and storage of hazardous chemicals, in accordance with federal and state regulations.

Provisions for managing the safe storage and use of hazardous chemicals which are integrated into the processing of radioactive materials or are generated by chemical reaction during processing include the following:

- Chemical evaluation during the design process to identify the hazards associated with the use and storage of hazardous chemicals.

- Administrative control through training and specific instructions contained in approved NFS procedures. This may include specific hazard warnings, personal protective equipment requirements, maintenance and lockout/tagout procedures, motorized vehicle procedures and/or spill response instructions.
- Routine audits and assessments as required by approved procedures.
- Engineering controls, as appropriate, for hazardous chemicals which have the potential to impact safety. These may include, but are not limited to, equipment design safety features such as pressure relief valves or interlocks, containment, ventilation, detection methods, and/or materials of construction.
- Controls for red oil incident are as identified by Fire Safety.

In addition to the general controls listed above, the Solvent Extraction area relies on nitric supply line isolation valves and spring-closed valves in the area as engineering controls. Other engineering controls include the glass knockout columns for overflow containment, compatible materials of construction, chemical makeup area dike containment, and welded elevated piping and drain caps on the nitric acid lines.

In the BPF process design, the majority of hazardous chemicals are piped into the process to minimize potential employee contact with the chemical during normal operations. In addition, most hazardous chemicals used in conjunction with radiological materials are handled inside process containment, with any vapors vented into the Wet Process Off-Gas System. Compressed Gas lines utilize pressure regulators, pressure indicators, flow meters, and pressure safety valves at appropriate locations in the line to insure safe operation.

As stated in the NFS Stormwater Pollution Plan, engineering controls for chemicals stored outside in bulk quantities at the NFS plant include secondary containment systems (dike or sump). Dike areas are not provided for compressed gas tanks. Chemical Spill Response Houses stocked with spill response supplies are located in areas where bulk chemicals are stored and/or unloaded.

Emergency Eye Washes and Safety Showers are located in areas where corrosive chemicals are used and are routinely inspected and tested in accordance with applicable NFS procedures.

Chemical controls for Solvent Extraction are summarized in Table 3-6.

3.3.2.3 Radiological Hazards and Controls – Worker (Solvent Extraction)

The Solvent Extraction Process uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the Solvent Extraction Process is the loss of containment of the radiological materials being processed. Containment is maintained by materials of construction and verified by the radiological monitoring program.

Radiological Hazards:

The radiological hazards or Material at Risk (MAR) that could potentially be affected by an event in the solvent extraction operation are summarized in Table 3-6.

The uranium materials are enriched in the isotope ^{235}U and include progeny of the isotopes of uranium as well as other radionuclides. Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the MAR did not meet the criteria for intermediate or high consequences to the worker. The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects, shock effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

The BPF will be a Controlled Area and engineering as well as administrative radiation protection controls will be utilized in the Solvent Extraction Operation. Personnel training and approved procedures will be provided to allow for safe operation and quick detection of any unfavorable trend so that appropriate corrective action can be implemented. The controls afforded by NFS' Radiation Protection Program for BPF will maintain airborne radioactivity, contamination levels, and radiation levels within specified limits to protect against occupational radiological hazards associated with operations in Solvent Extraction. For the red oil explosion scenario evaluated in Section 4.2, it is conservatively assumed the designation of High consequences. The IROFS credited are as identified by Fire Protection.

Radiological controls for the Solvent Extraction are summarized in Table 3-6.

3.3.2.4 Fire and Explosion Hazards and Controls (Solvent Extraction)

Accidental Solvent Release and Ignition in SX Process Area

The solvent used in the SX process consists of typically 15% by volume of tributyl phosphate (TBP) and 85% Norpar-12. This is verified semi-annually. Norpar-12 is 98% linear paraffins, primarily C11 to C12. The flashpoint of the Norpar-12 is 150°F. The autoignition is 400°F. The specific gravity is 0.75. Vapor pressure is less than 1 mm Hg at 70°F. It boils at 365-430°F. Norpar-12 is stable and will not react violently with water. The flashpoint for TBP is 295°F. The autoignition temperature is greater than 899.6°F. The specific gravity of TBP is 0.976. Vapor pressure is very low; approximately 1 mm Hg at 68°F. The combined flashpoint of the solvent mixture is 168°F.

Approximately 81 gallons of solvent is cycled through the first pass SX process. Approximately 68 gallons of solvent is cycled through the second pass SX process.

The entire SX process is separated from other BLEU Preparation Facility processes by minimum 2-hour fire rated construction. First-pass SX equipment is located along the east wall, the second-pass SX equipment along the west wall. Physical separation between first and second-pass equipment is approximately 20 feet.

Accidental solvent release potentials in the SX process area include:

- Process column overfilling
- Leakage from valves, pumps, piping
- Leakage at the column from gaskets, connection collars, cracking of the glass column (i.e., column breakage)
- Spill during sampling, maintenance
- Spill during system inventory

Diking was installed around first-pass and second-pass process columns and pumps, which handle solvent. 1st Pass dike is designed to hold 129 gallons, which is greater than the quantity used in chemical make-up or within 1st Pass. 2nd Pass dike is designed to contain 122 gallons, which is greater than the quantity used in chemical make-up or within 2nd Pass.

Process column overfilling, which could be caused by operator error or failure of a metering pump controller, would be vented to a knockout column.

The SX process design includes the following provisions:

- Use of hard piping and a dedicated pump for each SX system to drain the process columns into the raffinate columns for inventory (twice a year only).
- All process equipment will be corrosion resistant, including all screws and washers, gasket collars, etc. used on flanges and column connections (i.e., should be stainless steel). Pre-startup QA will include verification of proper materials and sign-off.
- To the highest degree possible, stainless steel tubing will be welded. In general, the use of screwed fittings and flanged connections will be minimized.

- In regard to gaskets, PTFE (Teflon grade) gaskets or similar gaskets with service temperatures to 500°F, gel points (i.e., start of thermal degradation and melting) in the range of 600-650°F, and self-extinguishing characteristics (i.e., combustion will cease if flame is removed) will be used.

These design features will minimize both the likelihood and size of an accidental solvent release. If a release does occur, it will be contained within the diked area. Should a release propagate outside the diked area, the 2-hour rated fire barrier walls which isolate the SX process act as a secondary containment measure.

Ignition Potentials

Ignition source potentials include electrical equipment, evaporators, and hot work.

All electrical equipment will be designed in strict accordance with NFPA 70, *National Electrical Code*®. Electrical switches, controllers, and panels will be rated NEMA 4X. This will provide protection against solvent liquid spray release ignition (i.e. NEMA 4X equipment is liquid tight and protects against corrosion).

The SX evaporators are located approximately 11 feet away from both first-pass and second-pass process equipment which handle solvent. The electric heaters are approximately 4-6 feet above the floor level and are equipped with over-temperature shutdown features. The maximum heater operating temperature (270°F) is well below the 400°F solvent ignition temperature.

Any hot work conducted in the SX process area will strictly follow NFS procedures, which require a hot work permit and an established fire watch.

The solvent is fairly viscous. If accidentally released from containment it would settle into a slow moving spill and pooling configuration with insignificant evaporation. In order to produce an ignitable mixture, sufficient solvent vapor must be produced and mixed with air. This can only be accomplished if the quantity of solvent released is heated above its flashpoint of 168°F. The solvent is not heated anywhere in the process, and there is no identified heating mechanism which could cause ignition of a solvent pool inside the diked area.

On April 4, 2002, a solvent ignition sensitivity test was conducted. Five gallons of solvent were placed in a 4-foot by 4-foot test pan. Neither open flame surface impingement, exposure to a propane torch flame for over two minutes, or a 10 minute exposure to cheesecloth soaked in mineral spirits ignited and placed in the center of the pan on the solvent surface, could ignite this solvent. Therefore given a solvent release, the likelihood of ignition is considered unlikely in the SX process area.

Fire Modeling Results

Fire modeling was conducted to evaluate the radiant heat exposure and convective fire plume temperatures from a solvent fire occurring in the SX process area.

The selected bounding or design-basis fire assumed release of 81 gallons of solvent from first-pass extraction and ignition within the diked area, creating a large pool fire exposure.

The fire modeling results from the FHA indicated that radiant heat to the building structure, primarily the steel beams supporting the first-level steel mezzanine (located approximately 19 feet above ground floor level) was not sufficient in intensity or duration to cause any significant structural damage inside the SX process area. Further radiant heat modeling indicated that if the fire was contained within the first-pass SX process diking, thermal damage and secondary failures should not occur to the second-pass SX process equipment (second-pass SX columns are separated from first-pass SX columns by approximately 20 feet.).

Based on the fire modeling, convective fire plume temperatures from the design basis pool fire reached 517°F at the first level mezzanine level, which is well below the failure point of structural steel (which is approximately 1,000°F). Pool fire flame height was estimated at 8.6 feet to a maximum 17.2 feet for flame directly against a wall. Based on actual solvent fire test observations, the most likely flame height would be in the range of 8-12 feet. Therefore, flame impingement would not be expected on the steel beams supporting the first level steel mezzanine.

There is no thermal failure exposure to the concrete 2-hour fire barrier walls or to the second level steel mezzanine located approximately 34 feet above the ground floor level.

The fire duration was estimated at 36.45 minutes. Involvement of low flame spread, self-extinguishing plastic ducting or electrical cables would not add any significant heat release or temperature increases inside the SX process area, nor should this cause fire propagation between first-pass and second-pass columns.

The SX process is isolated by minimum 2-hour fire rated construction. Minimum 1.5-hour fire doors and fire dampers will be installed. The roof level in the SX process area is approximately 46 feet above ground floor level. The roof is metal deck panel on steel beams. If a pool fire occurred in the SX process area at the ground floor level, there is no thermal failure exposure to the roof.

Area smoke detection and alarms will be provided for employee notification and fire brigade response. Portable fire extinguishers will be located throughout the area.

Red Oil Explosion Potential in the SX Evaporator System

A red oil explosion could be created by accidental interaction of TBP-kerosene and aqueous metal nitrate solutions. The literature suggests that red oil formation is much less likely in TBP-NPH (NPH = normal paraffin hydrocarbon, or Norpar-12). This is one of the reasons that Norpar-12 was selected as red oil will form at a higher temperature if Norpar-12 is used. A red oil incident can cause an exothermic reaction with ensuing overpressure.

Red oil is created when an organic solution, usually tributyl phosphate (TBP) and its diluent, Norpar-12, comes in contact with an aqueous metal nitrate solution, uranyl nitrate. Red oil is stable below 266°F (130°C), but will react explosively when heated above 266°F (130°C). The decomposition of the solution, an exothermic reaction, occurs rapidly enough that a positive heat gain occurs, self-heating. This self-heating evolves explosive vapors that can cause an ensuing overpressurization event. It appears from a literature review, DOE document WSRC-TR-2000-00427, *Initiation Temperature for Runaway Tributyl Phosphate / Nitric Acid Reaction*, that for red oil reaction to occur, the temperature at which the reaction rate starts to significantly increase must exceed 266°F (130°C). Without evaporative heat loss through ventilation, the heat of reaction can cause self-heating below 250°F (121°C).

Based upon this information, the researched literature, and NFS reports # 21G-03-0242 dated September 3, 2003, 21G-03-0299 dated November 7, 2003, and 21G-03-0312 dated December 5, 2003, a red oil incident is credible.

Chemical Makeup Area Solvent Fire

A solvent solution of 15% by volume of tributyl phosphate (TBP) in Norpar-12 is prepared in a tank that will be located in the Mechanical Room, which is directly west of the SX area and is isolated from all process areas with minimum one-hour rated construction.

The solvent tank is empty when not making solvent, which is 99% of the year. There will be no TBP or Norpar-12 drums stored in this area when not making solvent.

The solvent tank and pumps are located above a sump in the mechanical equipment room. Area smoke detection, manual fire alarm, and portable fire extinguishers are present.

Due to the low fire risk of this operation, additional automatic fire suppression over this equipment (which is used approximately 16 hours per year) is not warranted.

Fire hazards and controls for Solvent Extraction are summarized in Table 3-6.

The controls identified in Table 3-6 are required by the FHA. The high steam temperature, pressure interlock, and loss of column interface flow switch are also designated as IROFS in Section 6.

3.3.2.5 Environmental Hazards and Controls – Public (Solvent Extraction)

The environmental hazards for the Solvent Extraction process are the hazardous chemicals and radiological materials that have the potential for being released outside the protected area of the site at levels above the criteria specified in 10 CFR 70.61. The levels of concern for environmental hazards defined by 10 CFR 70.61 are defined in Section 7. For the solvent extraction process, the hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions.

Environmental hazards for Solvent Extraction are summarized in Table 3-6.

Environmental Controls:

The red oil incident has the potential to result in a high environmental consequence. The Fire and Explosion Hazards and Controls section (3.3.2.4) provides details regarding this scenario and the items relied on to prevent the postulated event. Two other scenarios were determined to have the potential for exceeding the 10 CFR 70.61 action levels and are considered intermediate consequence events. The following environmental controls reduce the potential impact to the environment.

Environmental controls for Solvent Extraction are summarized in Table 3-6.

Table 3-6
Hazard Summary for Solvent Extraction Process

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	Backflow to unfav. geometry utility systems HEUN solution spill to floor HEUN solution spill in enclosure More than one 2-liter bottle in enclosure HEUN solution spill/leak to unfav. geometry container	Favorable geometry borosilicate glass and stainless steel columns Floor designed to not exceed 1.25-inch depth Favorable geometry piping and pumps Stainless steel sleeve through wall for fissile solution lines Column spacing to prevent interaction Passive overflows on columns and knockouts 2 overflow drains in enclosures Reflection barrier in enclosure	Interlocked chemical and utility supply valves that close on loss of system pressure Spring-closed isolation valves on nitric acid supply line use points Interlocked chemical makeup valves open only when pump is operating	Single container control in enclosure Only favorable geometry containers allowed in SX area Maximum 2-liter bottle or 1.25-inch pan for fissile material in SX area
Chemical	Nitric acid spill (67%, etc.) Uranyl nitrate spill Tributyl phosphate spill Norpar-12 spill Solvent mixture spill Soluble uranium intakeNitrogen release to the work area	Materials of construction and building code compliance Knockout column overflows Containment dikes for chemical makeup tanks Welded elevated piping and drain line caps on nitric acid lines	Utility and chemical supply interlocks and isolation valves Emergency eye wash and safety showers Spring closed isolation valves for nitric use points	Personnel training and approved procedures Routine audits and assessments Spill response procedures and supplies Cap discharge valve
Radiological	HEUN spill Raffinate solution spill Evap. cond. solution Red Oil incident	See Fire and Explosion controls for Red Oil accident	See Fire and Explosion controls for Red Oil accident Radiation Protection Program monitoring and instrumentation	See Fire and Explosion controls for Red Oil accident Personnel training and procedures Radiation Protection Program controls

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Fire and Explosion	Solvent release and ignition in process area Red oil incident Chemical makeup area solvent fire	Rupture disc in steam line Compatible materials of construction Welded construction on piping Dikes around first pass and second pass columns and pumps Fire barrier walls separating SX area from HEU area and separating Mechanical Room and LEU area Sump in Mech. Room below chemical make-up tanks Phosphate Scrub Column 2B16 interface control of Strip Column 2B11 and Evaporator Feed Column 2P11 Reflux Columns vented preventing rupture and self-heating Concentrate Hold Columns 2O14/2O24 vented to prevent self-heating Columns downstream of the Concentrate Hold Column 2P14 vented to Knockout Column	High steam temp. and press. interlock Loss of interface flow switch Smoke detection and alarm system SX Interlock for loss of flow to Column 2A11/2B11, pump stops Evaporator 2O16 or 2P16 solution temperature reaches 110°C, power removed from Heaters 2O18/2O19 or 2P18/2P16 SX Interlock for steam temperature or pressure, Heaters 2O18/2O19 or 2P18/2P19 shutdown	Hot work area controls for SX area Verify no solvent in Concentrate Hold Columns prior to transfer Solvent make-up verified semi-annually Portable fire extinguishers throughout area Verify valve isolations during dissolution

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Environmental	Nitric Acid (67%) Spill Uranyl Nitrate Solution Spill [Nitric Acid Solution] Nitric Oxide Vapor Release Sodium Carbonate, Sodium Hydroxide, Sodium Nitrate, and Barium Nitrate Spill Tributyl Phosphate Spill Norpar-12 Spill HE UN Solution Spill Raffinate Solution Spill Fire Scenario involving ≤ 100 gallons solvent Fire Scenario involving ≥ 100 gallons and ≤ 149 gallons of solvent Red Oil Incident	Materials of construction Dike containment HEPA filters Process Exhaust Ventilation scrubber	Process interlocks Fire safety controls	Procedures and Training

3.4 DOWNBLENDING PROCESS

3.4.1 Process Description

The Downblending process involves blending of HEU material of varying enrichments with a natural uranium blendstock material, to produce an LEU product with an enrichment of approximately 5 weight % ^{235}U. The uranium materials are blended in the form of uranyl nitrate. The blendstock is received as uranium oxide and is dissolved in nitric acid. The process is operated at ambient temperature and pressure and the tanks are vented. The Downblending process in Building 333 will be the same as the 200 Complex process described in Section 15.3.13 of NRC License SNM-124.

High-Enriched UN Mix/Measurement and Staging Columns

High-enriched uranyl nitrate solution to be blended originates from two streams. The first stream is high-enriched uranyl nitrate from dissolution of uranium metal. The purity of this feed material is sufficient to eliminate the need for its purification through the solvent extraction system. After dissolution, the UN is staged in the BPF U Metal 7-day Test Columns. These columns (6-inch diameter borosilicate glass and 5-inch diameter stainless steel) are discussed in Section 3.1 as part of the U Metal Dissolution process.

The second stream is high-enriched uranyl nitrate from dissolution of uranium aluminum alloy. Following the dissolution of this feed material, the uranyl nitrate solution is purified via solvent extraction and the purified product is staged in the Solvent Extraction Product Columns (Section 3.3).

A blending batch is then determined based on the impurity concentration, uranium concentration, and uranium enrichment of these two uranyl nitrate streams. The appropriate volume of each stream is then pumped into the HEU Mix/Measure Columns and thoroughly mixed.

Finally, representative samples from the Mix/Measure columns are drawn and analyzed for uranium concentration and enrichment, as well as other process parameters. If necessary, the solution can be diluted with deionized water to meet uranium concentration limits. Once the desired concentration is achieved, the HEUN is transferred to the Staging Columns.

Blendstock Dissolution

Blendstock, natural uranium oxide (UO_3), is emptied from drums, conveyed into a dissolver tank, and mixed with heated nitric acid and water. This uranyl nitrate, $UO_2(NO_3)_2$ is typically prepared at a concentration of 350 to 400 gU/l.

The natural uranium dissolution process consists of four major components:

- Uranium oxide drum handling
- Uranium oxide feeder
- Uranium oxide conveyor
- Dissolver vessel (stainless steel,
)

Upon completion of the batch, confirmatory samples are drawn and analyzed to ensure the uranium concentration and enrichment are known prior to transferring the blendstock solution to the blending tank. The level controllers on the blendstock tank ensure that a minimum volume of natural UN is transferred to the blending tank.

Natural Dissolution Tank Trailer Loading

Although blendstock is normally transferred to the blending tank, it may also be prepared for direct shipment off site. After a batch is made in the Natural Dissolution Tank and has been certified by quality assurance, it may be transferred to a tank trailer for shipment. The tank trailer will be parked on a concrete pad on the west side of the BPF. From a platform, an operator connects flexible hoses for process solution and ventilation to the tank trailer. A control panel on the exterior of the building will assure all connections are made before the dissolver pump is started. Tank pad storm drainage is directed to a local below grade 500-gallon sump.

Enrichment Blending

LEU Hold Tank

The LEU Hold Tank is used to hold a batch quantity of low-enriched uranyl nitrate solution for transfer to the Uranyl Nitrate Building (UNB). The UNB is addressed in a separate ISA summary. Once transferred to the LEU hold tank, the solution is recirculated, sampled for impurities, and verified to meet the product specification. The LEU Hold tank is constructed of stainless steel, . After release from QC, the solution will be pumped to the UNB facility. After each transfer the line will be blown clear with plant air.

3.4.2 Hazards Identification and Controls (Downblending)

A summary table of the hazards and controls for Downblending is included as **Table 3-8.**

3.4.2.1 Criticality Hazards and Controls (Downblending)

The Downblending process brings HEUN into the recirculating natural UN (NUN) stream, and then empties the resulting LEUN into an unfavorable geometry tank. Each blend batch is designed with a preset recipe to ensure the ^{235}U concentration remains below an always-safe concentration. Therefore, the primary Nuclear Criticality Safety hazard is overconcentration of the LEUN in the Downblending tank. Primary engineered controls to prevent this sequence include redundant volume controls for both HEUN (batch control) and NUN (minimum level controls) feed streams, redundant density controls for the HEUN feed stream, and ^{235}U concentration control (gamma monitor) for the blended LEUN stream. Administrative controls include verification of the feed stream concentrations, enrichments, and volumes.

In order to ensure these controls are not exceeded, the following Limiting Condition for Operation (LCO) values are specified in the Nuclear Criticality Safety Evaluation (NCSE):

Controlled Parameter	LCO Value
Max LEU ^{235}U Concentration	11.78 g ^{235}U/l
Min Blendstock Volume	13,500 l
Max HEU Volume	500 l
Max HEU U Concentration	365 g U/l
Max HEU Enrichment	65.0 wt%

Overconcentration of the LEUN can also occur by evaporation and precipitation. Engineered controls for these contingencies include the use of water seals on tank overflow and vent lines and the lack of precipitating agent piping in the LEUN area.

Another NCS sequence is the backflow of HEUN into unfavorable geometry utility supply systems such as deionized water, and nitrogen. Engineered controls to prevent this sequence include interlocked supply valves and passive overflows on equipment containing HEUN.

The final NCS sequence is the transfer of HEUN to an unfavorable geometry (UFG) container in the HEUN area of Downblending. This sequence is prevented by the restriction of UFG containers from the HEUN area. There are no UFG tanks in the HEUN area of the BPF. Smaller, portable UFG containers are also restricted from the area entirely.

Criticality hazards and controls for Downblending are summarized in Table 3-8.

3.4.2.2 Chemical Hazards and Controls – Worker (Downblending)

Chemical Inputs or byproducts in the Downblending area which have established employee exposure limits or present physical hazards include:

- HE, LE, and Natural Uranyl Nitrate - radioactive material, corrosive, oxidizer
- Uranium Oxide - radioactive material
- Nitric Acid, 67 percent by weight - oxidizer, corrosive
- Nitrogen gas - asphyxiant

Other inputs include process water, deionized water and compressed air.

Chemical Reactions:

$$UO_3 + 2HNO_3 \rightarrow UO_2(NO_3)_2 + 2H_2O$$

Table 3-7 (Chemical Hazard Interaction Matrix – Downblending) is provided for consideration of Downblending chemical hazards.

Chemical Hazards:

The downblending process is operated at ambient temperature and pressure. Tanks are vented and there is no heating system associated with the process. No heat of reaction issues exist with the blending process.

A spill of 67 percent Nitric Acid resulting in a loss of contents of the [redacted] gallon bulk tank would potentially result in an employee exposure above the ERPG-3 level. Unmitigated, this would be classified as a high consequence event. The exact amount of the spill would be dependent on the severity of the line break or leak, or the severity of the valve failure or leak. The amount of the spill would also be dependent on the time until operator intervention. Isolation valves on the

bulk nitric acid input lines to the building would prevent a spill through a line break or valve failure when the building was unoccupied.

During normal operations, employee exposure to chemical vapors involved in the dissolution of Natural Uranium and the Downblending of HEU and LEU product streams are controlled through process exhaust ventilation. In the event of a Uranyl Nitrate spill, employee exposure to nitric acid would not be expected to be above the established ERPG-2 limit. A release of nitrogen to the work area would not be expected to create an oxygen deficient atmosphere.

NO_x emissions are produced during the natural dissolution process. Under normal operating conditions, these emissions are routed through the scrubber system for removal. In the event of process ventilation failure or a breach of ductwork integrity during processing, NO_x vapors could be released to the work area. This release would have the potential to exceed the ERPG-3 limit for nitrogen dioxide.

Several scenarios could result in a potential employee intake of soluble uranium, such as an overall containment failure of the dissolution tank, blend tank, or hold tank or a possible breach during the filling of the tanker. Unmitigated, these scenarios could potentially result in an intermediate consequence. Tank 4C01 and 4D04 are equipped with overflow lines to prevent overpressurization conditions that could result in an overall containment failure, while the tanker is equipped with a rupture disc. Tanks 4C01 and 4D04, and the tanker, are connected to the POG system.

Chemical hazards for Downblending are summarized in Table 3-8.

Table 3-7
Chemical Hazard Interaction Matrix - Downblending

Chemical Name	Comp. Air	Cooling Water	DI Water	Nitric Acid	Nitrog. (gas)	NO_x vapor	Uranyl Nitrate	UO_3
Compressed Air	same	none	none	none	none	none	none	none
Cooling Water	[illegible]	same	none	4	none	4	none	none
DI Water	[illegible]	[illegible]	same	4	none	4	none	none
Nitric Acid, 67% (solution)	[illegible]	[illegible]	[illegible]	same	4	4	4	1,5
Nitrogen (gas)	[illegible]	[illegible]	[illegible]	[illegible]	same	none	none	none
NO_x (vapor)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	none	1,6
Uranyl Nitrate (solution)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same	1
UO_3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	same

1=Heat generated from chemical reaction may initiate explosion.

2=May cause fire.

3=Flammable gas generation.

4=Heat generation by chemical reaction, may cause pressurization.

5=Can become highly flammable in use; causes pressurization.

6=Contact with substance liberates toxic gas; causes pressurization.

7=Innocuous and nonflammable gas generation; causes pressurization.

Chemical Controls:

It is the policy of NFS to minimize the risk associated with the use and storage of hazardous chemicals, in accordance with federal and state regulations.

Provisions for managing the safe storage and use of hazardous chemicals which are integrated into the processing of radioactive materials or are generated by chemical reaction during processing include the following:

- Chemical evaluation during the design process to identify the hazards associated with the use and storage of hazardous chemicals.
- Administrative control through training and specific instructions contained in approved NFS procedures. This may include specific hazard warnings, personal protective equipment requirements, maintenance and lockout/tagout procedures, motorized vehicle procedures, and/or spill response instructions.
- Routine audits and assessments as required by approved procedures.
- Engineering controls, as appropriate, for hazardous chemicals which have the potential to impact safety. These may include, but are not limited to, equipment design safety features such as pressure relief valves or interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition to the general controls listed above, the Downblending area would rely on nitric acid supply line isolation valves as engineering controls. Other engineering controls include the glass knockout column, compatible materials of construction, and welded elevated piping on the nitric acid input lines. Over temperature controls on the heater and a heat exchanger are used in the natural dissolution process to maintain a designated temperature range. Tank overflows and POG lines provide pressure relief on the dissolution tank, blend tank and the hold tank. The UN tanker has a tanker rupture disc to provide pressure relief, and the control panel has an emergency stop for administrative control actions.

An administrative control is required to provide for nitric acid supply isolation if the blendstock dissolution tank level is high, preventing tank overflow.

In the BPF process design, the majority of hazardous chemicals are piped into the process to minimize potential employee contact with the chemical during normal operations. In addition, most hazardous chemicals used in conjunction with radiological materials are handled inside process containment, with any vapors vented into the Wet Process Off-Gas System. Compressed Gas lines utilize pressure regulators, pressure indicators, flow meters, and pressure safety valves at appropriate locations in the line to insure safe operation.

As stated in the NFS Stormwater Pollution Plan, engineering controls for chemicals stored outside in bulk quantities at the NFS plant include secondary containment systems (dike or sump). Dike areas are not provided for compressed

gas tanks. Chemical Spill Response Houses stocked with spill response supplies are located in areas where bulk chemicals are stored and/or unloaded.

Emergency Eye Washes and Safety Showers are located in areas where corrosive chemicals are used and are routinely inspected and tested in accordance with applicable NFS procedures.

Chemical controls for Downblending are summarized in Table 3-8.

3.4.2.3 Radiological Hazards and Controls – Worker (Downblending)

The Downblending Process uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the Downblending Process is the loss of containment of the radiological materials being processed. Containment is maintained by materials of construction and verified by the radiological monitoring program.

Radiological Hazards:

The radiological hazards or Material at Risk (MAR) that could potentially be affected by an event in the Downblending process are summarized in Table 3-8.

The uranium materials are enriched in the isotope ^{235}U and include progeny of the isotopes of uranium as well as other radionuclides. Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the MAR did not meet the criteria for intermediate or high consequences to the worker. The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

The BPF is a Controlled Area and engineered as well as administrative radiation protection controls are utilized in the Downblending Process. Personnel training and approved procedures provide for safe operation and quick detection of any unfavorable trend so that appropriate corrective action can be implemented. The controls afforded by NFS' Radiation Protection Program for BPF maintain airborne radioactivity, contamination levels, and radiation levels within specified limits to protect against radiological hazards associated with operations in Downblending. There are no IROFS identified for the Downblending process based on Section 4.2 Radiological Consequence Analysis.

Radiological controls for Downblending are summarized in Table 3-8.

3.4.2.4 Fire and Explosion Hazards and Controls (Downblending)

Potential hazards associated with the Downblending process include:

Natural UO_3 Powder

Based on the MSDS sheet for UO_3 powder provided by Cameco Technical Services, this powder does not present a fire hazard. This material has no listed flash point as it is a solid, is listed as stable, and will not polymerize.

As a result of research and conversations with Cameco technical staff, UO_3 powder does not present a fire or explosion hazard and therefore does not require any special electrical classifications or fire protection features.

Drum Lift Hydraulic Fluid

A hydraulic drum lift will be used to lift and tilt a maximum weight of [redacted] lbs. of UO_3 powder into a hopper. The quantity of hydraulic fluid is approximately 2.5 gallons. A fire resistive, low hazard hydraulic oil will be used.

Due to the small quantity and type of oil, a hydraulic fluid fire presents a minimal exposure to equipment in this area which primarily consists of steel tanks and presents a negligible exposure to the steel columns located in this area which support the mezzanine.

Tank Trailer Loading

A tank trailer is parked at a loading station along the outside west wall of the BPF. Natural UN is pumped from a tank in the Downblending process area to the tank trailer. The transfer line will be noncombustible.

The west wall of the BPF has an equivalent fire rating of 1.5 hours. The exit door in the vicinity of the truck loading area has a 1.5-hour rating. This operation does not present a significant external fire hazard exposure to the Downblending process equipment located inside Building [redacted]

Fire hazards and controls for Downblending are summarized in Table 3-8.

Because a fire may cause an intermediate environmental consequence, the tank trailer loading area sump is added as a fire IROFS. The control in Table 3-8 is required by the FHA. Since this control was not required to prevent exceeding the 10 CFR 70.61 exposure criteria, it is not listed in Section 6 as an IROFS.

3.4.2.5 Environmental Hazards and Controls – Public (Downblending)

The environmental hazards for the Downblending process are the hazardous chemicals and radiological materials that have the potential for being released outside the protected area of the site at levels above the criteria specified in 10 CFR 70.61. The levels of concern for environmental hazards defined by 10 CFR 70.61 are defined in Section 7. For the Downblending process, the hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions.

Environmental hazards for Downblending are summarized in Table 3-8.

Environmental Controls:

Two postulated accident sequences resulting in a nitric acid spill (67%) have the potential to result in a high environmental consequence. One postulated accident sequence resulting in the overflow of the natural dissolution system has the potential to result in a high environmental consequence. Some accident sequences involving HEUN solution, LE UN solution, and Natural UN solution resulted in intermediate consequences. The other environmental consequences evaluated for the Downblending process do not exceed action levels specified in 10 CFR 70.61 and are considered low consequence events. The following IROFS and environmental controls are provided to reduce the potential impact to the environment.

Environmental controls for Downblending are summarized in Table 3-8.

Table 3-8
Hazard Summary for Downblending Process

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	High concentration UN in unfav. geometry tank Backflow of high concent. UN in utility systems Leak of HEUN to unfav. geometry container	Favorable geometry mix/measure columns Passive overflows on column and knockouts Passive floor design to prevent >1-inch in HEUN area	Interlocked utility system supply valves that close on loss of system pressure Redundant interlocked HEU feed valves close on high concentration, high feed volume, low blendstock volume, and high flow	Only favorable geometry containers allowed in HEU area Verification of enrichment sample results prior to blending Container lids in place Verification of level in blend and hold tanks 2-liter bottles or less for fissile material
Chemical	Nitric acid spill (67%) Uranyl nitrate spill Nitrogen release to the work area NO_x release to the work area	Materials of construction, welded elevated piping, and building code design requirements Heat exchanger sized to remove maximum heat of reaction from U natural dissolver Knockout column overflows Blend tank overflow Dissolution tank overflow UN tanker rupture disc and fill line POG lines	Temperature controls on natural U dissol. process Utility and chemical supply interlocks and isolation valves Overtemperature controls on heater Emergency eye wash and safety showers Nitric supply isolation upon high level in blendstock dissolution tank	Personnel training and procedures Routine audits and assessments Nitric supply isolation upon high level in blendstock dissolution tank UN tanker control panel emergency stop for admin. action Loss of ventilation action Operator action on NO_x detection and alarm Tanker POG vented
Radiological	HEUN solution LEUN solution Natural UN solution Natural UO_3 powder	Separation of Downblending process area	Rad. Prot. Prog. monitoring and instruments	Personnel training and procedures Rad. Prot. Program controls

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Fire and Explosion	Natural Uranium oxide powder Drum lift hydraulic oil Tanker loading	Tank trailer loading area sump West wall 1.5 hour rated fire barrier	Overtemperature shut down control on dissolver tank heaters	None
Environmental	Nitric Acid Spill (67%) Nitric Oxide Vapor Release LE UN Solution Spill Nat. UN Solution Spill UO_3 Dispersion (Spill) UO_3 Dispersion (Spill & Fire) Nat. UN Solution Spill/Fire HEUN Solution Spill	Materials of construction and elevation LEU Area Dike Welded stainless steel nitric lines Double-lined underground BLEU Complex line UN Tanker rupture disc Tanker loading area sump UNB input line is elevated or protected DOT certification requirements on UN Tank Trailer	HEPA Filters Process Exhaust Ventilation scrubber Nitric supply isolation from bulk timer switches and from blendstock dissolution tank high level indication	Procedures and Training DI water and nitric supply isolation on high level in blendstock dissolution tank Isolation of natural solution line except during transfer to tanker

3.5 LIQUID WASTE DISCARD TANKS

3.5.1 Process Description

During BPF processing, liquid waste discard streams are collected and transferred to either one of two condensate discard tanks or the caustic discard tank. These three cylindrical tanks are constructed of stainless steel,

All three tanks are located inside the northwest corner of the BPF process area.

The condensate discard tanks (TANK-5A01 and TANK-5A03) receive condensate solution discharged from the SX system. Condensate is pumped from BPF evaporator condensate columns bank E and bank F, which are fed from the 1st and 2nd pass evaporation condensers.

The caustic discard tank (TANK-5B01) receives solution discharged from the centrifuge resulting from the dissolution of high-enriched uranium/aluminum (HE UAl) alloy ingots. Caustic solution is pumped from BPF UAl dissolution caustic discard bank G and bank H . Both the condensate discard tanks and the caustic discard tank are used as intermediate storage before releasing solution to the Waste Water Treatment Facility (WWTF).

Condensate Discard Tanks

The condensate solutions from SX are mixed and sampled in the respective hold columns (Bank A or Bank B). After dual sampling and lab analysis, they will be transferred to the discard tanks through a block and bleed double valve arrangement. These tanks are used to collect the solutions and may provide for final MC&A measurement of the uranium present before transferring to the WWTF.

The common transfer line for the two condensate waste streams includes one in-line radiation monitor to assure safe transfer of materials from favorable to unfavorable geometry. Dual isolation valves are interlocked with the detector to prevent solutions with high concentrations from entering the tank. The tank also has a level transmitter and high level switch and alarm. Ventilation is provided to capture fugitive gases on the tanks.

Caustic Discard Tank

The caustic discard solution from the UAl dissolution centrifuge operation is mixed and sampled in the discard hold columns (Bank A and Bank B). After dual sampling and lab analysis, and the solution is

transferred to the caustic discard tank through a block and bleed double valve arrangement. The equipment, controls and operation of the caustic discard tank are identical to the condensate discard tanks.

Discard Tank Dike and Enclosure

The discard tanks are mounted on legs approximately 3 feet above a concrete dike area sized to contain the largest volume vessel. Two other bulk chemical tanks are inside the dike. These tanks hold sodium nitrate and caustic solutions used for UAl dissolution. Operation of these tanks is discussed in the UAl process description. The dike floor is sloped to one corner to allow clean up of spills. The discard tanks are located in a completely enclosed area inside the northwest corner of Building 333.

3.5.2 Hazard Identification and Controls

A summary table of the hazards and controls for the Liquid Waste Discard Tanks is included as **Table 3-10.**

3.5.2.1 Criticality Hazards and Controls (Liquid Waste Discard)

As described above, liquid effluent from the UAl dissolution centrifuge process and SX condensate process is discharged from safe geometry hold columns to the large, unfavorable geometry waste discard tanks (TANK-5A01, TANK-5A03 and TANK-5B01). A potential criticality hazard would exist if greater than 605 grams of ^{235}U were introduced into either of these tanks.

Controls have been defined to prevent greater than 605 grams ^{235}U from entering, or accumulating inside, the tanks. These controls are discussed in detail below.

After TANK-5A01, TANK-5A03 and TANK-5B01 have been determined to meet established acceptance criteria, the liquid is pumped out of the tanks to the Waste Water Treatment Facility (WWTF). Due to the caustic nature of the solution inside TANK-5B01, any uranium inside the tank is expected to be in a solid form. A fixed radiation detector system is installed to perform an NDA scan each time the tank is drained to minimize the potential that unacceptable levels of uranium accumulation inside TANK-5B01 will go undetected. A limit on the amount of allowable uranium solids holdup in TANK-5B01 is set at 50 grams ^{235}U. If greater than this amount of uranium is detected by the NDA scan, action must be taken to rinse, clean or otherwise remove the holdup solids.

Conversely, any uranium inside TANK5A01/5A03 is expected to remain in solution (rather than precipitating as a solid) because the pH of the solution in these tanks will never be greater than approximately that of distilled water. Data indicates that uranium is soluble to 650 grams per liter in a 0 M uranyl nitrate solution (essentially a solution of uranium in water). There are no identified

credible sources of caustic available to these tanks from the BPF solvent extraction system, or otherwise. Therefore, periodic scans for solid uranium holdup in TANK-5A01/5A03 are not required.

Liquid effluent from the UAl dissolution process is stored in safe geometry hold columns until the ^{235}U concentration in the liquid can be demonstrated, by way of sampling and analysis, . First, the columns are isolated from all other sources of fissile solution. The contents of the columns are then mixed by recirculation to homogenize and ensure that samples drawn are representative of the solution at large. Two samples are drawn and sent to the laboratory where each is analyzed for ^{235}U concentration. Insofar as is practicable, controls are in place to provide independence between the collection, labeling, analysis, and reporting of results for the two samples. These controls prevent, or minimize any potential for repeated or common cause failure. If results indicate a ^{235}U concentration , the contents of the columns are recycled or diluted, and the sampling and analysis is repeated. When favorable results are achieved, the columns are discharged to the appropriate waste discard tank through the double valve block and bleed arrangement.

Before entering TANK-5A01, TANK-5A03 or TANK-5B01, liquid effluent passes through a pipe that is constantly monitored by a gamma ray detector. The monitor is interlocked with two downstream redundant isolation valves that close and terminate solution transfer if the detector measures an unacceptably high ^{235}U concentration in the liquid. The monitor actuation set point is chosen to prevent greater than 555 grams ^{235}U from being delivered into the tank.

Criticality hazards and controls for Liquid Waste Discard are summarized in Table 3-10.

3.5.2.2 Chemical Hazards and Controls – Worker (Liquid Waste Discard)

Chemical Inputs or byproducts in the Liquid Waste Discard System which have established employee exposure limits or present physical hazards include:

- Nitric Acid
- Sodium Hydroxide
- Sodium Nitrate
- Sodium Nitrite
- Sodium Aluminate
- Barium Nitrate
- Barium Carbonate

Other inputs include process water and compressed air. The Condensate Discard Stream consists of an approximately 1 Molar Nitric Acid solution discard from the uranium purification process. The Caustic Discard stream consists of a discard solution from the Uranium/Aluminum dissolution process.

Chemical Reactions:

No chemical reactions are expected inside the discard tanks.

Table 3-9 (Chemical Interaction Matrix - Liquid Waste Discard) is provided for consideration of Liquid Waste Discard chemical hazards.

Chemical Hazards:

A spill of 2000 gallons of a 1 Molar nitric acid solution would not be expected to result in an employee exposure above the ERPG-1 limit for a limited exposure time.

Calculations were performed assuming a mode of force that would result in an airborne release of dissolved solids. An overflow of the Caustic Discharge Tank, tank overpressurizations or a valve failure resulting in a spill, assuming a 1 centimeter spill depth in the dike discard area, would result in an intermediate consequence level event.

Chemical hazards for Liquid Waste Discard are summarized in Table 3-10.

Table 3-9
Chemical Hazard Interaction Matrix - Liquid Waste Discard

Chemical Name	Bar. Carb.	Barium Nitrate	DI Water	Nitric Acid	Sod. Alum.	Sod. Hydrox	Sod. Nitrite	Sod. Nitrate
Barium Carbonate	same	4,6	none	1,2,3,4,6	4	4	4,6	4,6
Barium Nitrate		same	none	4	4,6	4,6	none	none
DI Water			same	4	none	4	none	none
Nitric Acid (solution)				same	2,4	2,4	4	4
Sodium Aluminate (solution)					same	none	4,6	4,6
Sodium Hydroxide, 30% (solution)						same	4,6	4,6
Sodium Nitrite (solution)							same	none
Sodium Nitrate, 45% (solution)								same

1=Heat generated from chemical reaction may initiate explosion.

2=May cause fire.

3=Flammable gas generation.

4=Heat generation by chemical reaction, may cause pressurization.

5=Can become highly flammable in use; causes pressurization.

6=Contact with substance liberates toxic gas; causes pressurization.

7=Innocuous and nonflammable gas generation; causes pressurization.

Chemical Controls:

It is the policy of NFS to minimize the risk associated with the use and storage of hazardous chemicals, in accordance with federal and state regulations.

Provisions for managing the safe storage and use of hazardous chemicals which are integrated into the processing of radioactive materials or are generated by chemical reaction during processing include the following:

- Chemical evaluation during the design process to identify the hazards associated with the use and storage of hazardous chemicals.
- Administrative control through training and specific instructions contained in approved NFS procedures. This may include specific hazard warnings, personal protective equipment requirements, and/or spill response instructions.
- Routine audits and assessments as required by approved procedures.
- Engineering controls, as appropriate, for hazardous chemicals which have the potential to impact safety. These may include, but are not limited to, equipment design safety features such as pressure relief valves or interlocks, containment, ventilation, detection methods, and/or materials of construction.

In the BPF process design, the majority of hazardous chemicals are piped into the process to minimize potential employee contact with the chemical during normal operations. In addition, most hazardous chemicals used in conjunction with radiological materials are handled inside process containment, with any vapors vented into the Wet Process Off-Gas System. Compressed Gas lines utilize pressure regulators, pressure indicators, flowmeters, and pressure safety valves at appropriate locations in the line to insure safe operation.

As stated in the NFS Stormwater Pollution Plan, engineering controls for chemicals stored outside in bulk quantities at the NFS plant include secondary containment systems (dike or sump). Dike areas are not provided for compressed gas tanks. Chemical Spill Response Houses stocked with spill response supplies are located in areas where bulk chemicals are stored and/or unloaded.

Emergency Eye Washes and Safety Showers are located in areas where corrosive chemicals are used and are routinely inspected and tested in accordance with applicable NFS procedures.

Chemical controls for Liquid Waste Discard are summarized in Table 3-10.

3.5.2.3 Radiological Hazards and Controls – Worker (Liquid Waste Discard)

Hazard Description:

The Liquid Waste Discard Process uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the Liquid Waste Discard Process is the loss of containment of the radiological materials being processed. Containment is maintained by materials of construction and verified by the radiological monitoring program.

Radiological Hazards:

The radiological hazards or Material at Risk (MAR) that could potentially be affected by an event in the liquid waste discards process are summarized in Table 3-10.

The uranium materials are enriched in the isotope ^{235}U and include progeny of the isotopes of uranium as well as other radionuclides. Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the MAR did not meet the criteria for intermediate or high consequences to the worker. The releases evaluated included explosive release (i.e. pressurized venting effects), free fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

The BPF Liquid Waste Discards is a restricted area and engineering as well as administrative radiation protection controls are utilized in the Liquid Waste Discards Process. Personnel training and approved procedures provide for safe operation and quick detection of any unfavorable trend so that appropriate corrective action can be implemented. The controls afforded by NFS' Radiation Protection Program maintain airborne radioactivity, contamination levels, and radiation levels within specified limits to protect against occupational radiological hazards associated with Liquid Waste Discard operations. There are no IROFS identified for the Liquid Waste Discard operations based on the Radiological Safety Consequence Analysis documented in Section 4.2.

Radiological controls for Liquid Waste Discard are summarized in Table 3-10.

3.5.2.4 Fire and Explosion Hazards and Controls (Liquid Waste Discard)

The liquid waste discard tanks are located outside the BPF, and are surrounded by a concrete diked floor. No significant fire or explosion hazards have been identified for this process.

3.5.2.5 Environmental Hazards and Controls – Public (Liquid Waste Discard)

The environmental hazards for the Liquid Waste Discard process are the hazardous chemicals and radiological materials that have the potential for being released outside the protected area of the site at levels above the criteria specified in 10 CFR 70.61. The levels of concern for environmental hazards defined by 10 CFR 70.61 are defined in Section 7. For the Liquid Waste Discard process, the hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions.

Environmental hazards for Liquid Waste Discard are summarized in Table 3-10.

Environmental Controls:

All environmental consequences evaluated for the Liquid Waste Discard process do not exceed action levels specified in 10 CFR 70.61. All postulated accident scenarios were determined to be low consequence events and no environmental controls have been identified as items relied on for safety (IROFS). However, the following environmental controls reduce the potential impact to the environment.

Environmental controls for Liquid Waste Discard are summarized in Table 3-10.

Table 3-10
Hazard Summary for Liquid Waste Discard Tanks

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	Waste discard tanks are unfavorable geometry Liquid waste streams connected to discard tanks have potential to exceed acceptable concentrations	Smooth internal surface and conical bottom for discard tanks	In-line concentration monitor to stop transfer to discard tanks	NDA scans, and cleanout requirements to prevent holdup in tanks. Isolation, mixing, sampling, and analysis requirements in transfer procedures and training
Chemical	Nitric acid spill (1 molar) Caustic discard solution spill (sodium hydroxide, sodium nitrate, and nitrite, sodium aluminate, barium nitrate and barium carbonate)	Materials of construction and building code design requirements Containment dikes Caustic discard tank overflow	Process exhaust ventilation system (off-gas)	Personnel training and procedures Routine audits and assessment Spill response procedures and supplies
Radiological	Caustic waste solution Nitric waste solution	Separation of Liquid Waste Discard process area	Rad. Prot. Prog. monitoring and instruments	Personnel training and procedures Rad. Prot. Program controls
Fire and Explosion	None	None	None	None
Environmental	Uranyl Nitrate Spill (5% Nitric Acid) Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution Spill Nitric Oxide Vapor Release SX Condensate Solution Spill Caustic Discard Solution Spill	Materials of construction Dike HEPA filters Process Exhaust Ventilation Scrubber	Process Interlocks	Procedures and Training

3.6 PROCESS EXHAUST VENTILATION SYSTEM

3.6.1 Process Description

The BPF process exhaust ventilation is used to remove airborne uranium particulate from the U metal and UAl process enclosures, and to scrub the NO_x vapors from the exhaust gas streams. Any source point within the process exhaust ventilation that may contain particulate uranium has HEPA filtration. Process exhaust ventilation is also pulled from process off gas (POG) lines and wet off gas (WOG) lines throughout the system. The POG lines are used to remove vapors and provide ventilation to gloveboxes and equipment that are considered dry operations. WOG lines provide ventilation through knockout columns to process columns, and operations that may involve liquids.

The process exhaust ventilation is pulled through the POG and WOG lines into the process exhaust ventilation ductwork. A series of three separate blowers are used to provide the process exhaust ventilation throughout the ductwork system. Condensate drain columns are installed throughout the ventilation ductwork to collect any moisture that may collect within the ductwork system. The process exhaust ventilation is then vented to the outside atmosphere through the main ventilation exhaust stack.

Process exhaust effluent pulled from wet process steps is scrubbed prior to being sent to the exhaust stack. The scrubber is a sieve tray design, in which the effluent is pulled up through a series of trays through which the scrubbing solution is gravity fed. The process exhaust effluent is then pulled through a demister and sent to the main plant exhaust stack. The scrubbing solution is collected at the bottom of the scrubber and is recirculated through the scrubbing trays. The scrubbing solution is monitored for pH and conductivity to ensure proper scrubbing occurs and that there is no precipitation within the scrubber.

The scrubber is periodically blown down to the scrubber blowdown tank (Tank 6H05). This 1000-gallon tank holds the used scrubber solution until it is sent to the Waste Water Treatment Facility. The blowdown tank has the ability to recirculate the scrubber solution, and has a mixer that ensures the solution is homogeneous and no precipitation occurs.

3.6.2 Hazard Identification and Controls

A summary table of the hazards and controls for the Process Exhaust Ventilation System is included as Table 3-12.

3.6.2.1 Criticality Hazards and Controls (Process Exhaust Ventilation System)

HEPA filter loading

A HEPA filter loaded to its maximum credible loading, with uranium particulate, is considered a normal condition. Calculations show that this condition is safe and of no criticality safety concern. A differential pressure indicator is installed at each HEPA filter to provide the operators a visual indication of when the HEPA filter needs changing. Procedures and training are in place to ensure that the filter is replaced when needed and handled in accordance with criticality safety limits.

Uranium particulate/solution accumulation in the ductwork

Accumulation of uranium particulate or solution within the process exhaust ventilation ductwork is expected to occur during normal and off normal operations. Uranium particulate will accumulate in areas of the ductwork system where there are changes in velocity of the process exhaust ventilation and changes in direction of flow. Periodic NDA scanning of the ductwork system ensures that uranium does not accumulate beyond a safe mass. NDA scanning and visual inspection of the ductwork helps determine when a cleanout of the ductwork system is needed.

Uranium accumulation in the scrubber

Uranium accumulation in the scrubber, both solids and solutions, are expected to occur during normal and off normal operations. The scrubbing solution will collect uranium from the process exhaust ventilation. This scrubbing solution is collected in the bottom of the scrubber and periodically blown down to the blowdown tank. Over a period of time, solid uranium can accumulate at the bottom of the scrubber. Dual independent sampling of the scrubber solution ensures that the solution that is blown down to the blowdown tank and transferred to the Waste Water Treatment Facility is below the set concentration limit for the tanks at the Waste Water Treatment Facility. Periodic NDA scans and visual inspection of the scrubber ensure that uranium does not accumulate beyond a safe mass and determines when the solids at the bottom of the scrubber need to be cleaned out.

Uranium accumulation in the blowdown tank

Normal operations of the process exhaust ventilation system blowdown tank assumes the presence of uranium bearing solutions. Dual independent samples of the solution are taken to ensure that it meets the concentration limits associated with the waste discharge tanks at the Waste Water Treatment Facility. To prevent the precipitation and gradual accumulation of solids in the tank over a period of time, the blowdown tank is recirculated with a pump to ensure proper agitation of the solution occurs. The tank also contains a mixer which aids in the mixing and

agitation of the solution until it is transferred to the Waste Water Treatment Facility. Periodic NDA scans and visual inspection of the scrubber ensure that uranium does not accumulate beyond a safe mass and determines when the solids at the bottom of the scrubber need to be cleaned out.

Concentration of uranium in the scrubber solution sent to the Waste Water Treatment Facility

To comply with the concentration limits associated with the tanks in the Waste Water Treatment Facility, several controls are in place. The main control to prevent a high concentration solution from being pumped to the Waste Water Treatment Facility is the dual independent sampling of all solution transfers to the WWTF. As defense in depth for concentration control, the source point HEPA filters are in place to prevent uranium material from entering the process exhaust ventilation system. Periodic NDA scans and cleanout of the process exhaust ventilation ductwork system also ensures that uranium bearing material does not accumulate in the ductwork or scrubber system over time and eventually migrate into the solution that is transferred to the WWTF.

Criticality hazards and controls for the Process Exhaust Ventilation System are summarized in Table 3-12.

3.6.2.2 Chemical Hazards and Controls – Worker (Process Exhaust Ventilation System)

Chemical Inputs or byproducts in the Process Exhaust Ventilation System which have established employee exposure limits or present physical hazards include: nitric acid, sodium hydroxide, NO_x emissions, hydrogen, and hydrogen peroxide. Other inputs include process water and compressed air.

A loss of ventilation with a potential exposure at the source points could result in an exposure above the ERPG-3 limit for nitrogen dioxide. This scenario was evaluated in the source point calculations. A potential explosion due to hydrogen buildup was also evaluated in source point calculations and could result in a high consequence event. A spill of 30% sodium hydroxide input from bulk chemical, assuming a 5 minute spill at a pump rate of 50 gallons per minute could result in an exposure above the ERPG-2 limit assuming a mode of force resulting in an airborne release of dissolved solids. A spill of 67% nitric acid input from bulk chemical could result in an exposure above the ERPG-3 limit.

No significant chemical reactions are expected inside the process ventilation system. Chemical hazards and controls are summarized in Table 3-11.

Table 3-11
Chemical Hazard Interaction Matrix – Process Exhaust Ventilation System

Chemical Name	Nitric Acid	Sod. Hyd.	Hyd.	Hyd. Peroxide	Nitrogen Dioxide	Process Water	Comp. Air
Nitric Acid	Same	2,4	1,2,3,4,5	5	5	5	None
Sodium Hydroxide	[illegible]	Same	5	5,6	5,6	5	None
Hydrogen	[illegible]	[illegible]	Same	1,2,4	1,2,4	None	None
Hydrogen Peroxide	[illegible]	[illegible]	[illegible]	Same	None	None	None
Nitrogen Dioxide	[illegible]	[illegible]	[illegible]	[illegible]	Same	None	None
Process Water	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Same	None
Compressed Air	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Same

1=Heat generated from chemical reaction may initiate explosion.
2=May cause fire.
3=Flammable gas generation.
4=Heat generation by chemical reaction; may cause pressurization.
5=Can become highly flammable in use; causes pressurization.
6=Contact with substance liberates toxic gas; causes pressurization.
7=Innocuous and nonflammable gas generation; causes pressurization.

3.6.2.3 Radiological Hazards and Controls – Worker (Process Exhaust Ventilation System)

The Process Exhaust Ventilation System uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the Process Exhaust Ventilation System is the loss of containment of the radiological materials being processed. Containment is maintained by materials of construction and verified by the radiological monitoring program.

Radiological Hazards:

The radiological hazards or Material at Risk (MAR) that could potentially be affected by an event in Process Exhaust Ventilation are summarized in Table 3-12.

The uranium materials are enriched in the isotope ^{235}U and include progeny of the isotopes of uranium as well as other radionuclides. Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the MAR did not meet the criteria for intermediate or high consequences to the worker. The releases evaluated included free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

The BPF is a Controlled Area and engineering radiation protection controls, as well as administrative, are utilized for Process Exhaust Ventilation hazards. Personnel training and approved procedures provide for safe operation and quick detection of any unfavorable trend so that appropriate corrective action can be implemented. The controls afforded by NFS' Radiation Protection Program for BPF maintain airborne radioactivity, contamination levels, and radiation levels within specified limits to protect against occupational radiological hazards associated with operations in Process Exhaust Ventilation. There are no IROFS assigned for Process Exhaust Ventilation based on the Occupational Health Physics Consequence Analysis.

Radiological controls for the Process Exhaust Ventilation System are summarized in Table 3-12.

3.6.2.4 Fire and Explosion Hazards and Controls (Process Exhaust Ventilation System)

No significant fire or explosion hazards were identified for the Process Exhaust Ventilation System. Fire hazards and associated controls for the air dilution ventilation system are addressed in Section 3.2.2.4 (UAl Dissolution).

3.6.2.5 Environmental Hazards and Controls – Public (Process Exhaust Ventilation System)

The environmental hazards for the Process Exhaust Ventilation are the hazardous chemicals and radiological materials that have the potential for being released outside the protected area of the site at levels above the criteria specified in 10 CFR 70.61. The levels of concern for environmental hazards defined by 10 CFR 70.61 are defined in Section 7. For the Process Exhaust Ventilation process, the hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions.

Environmental hazards for the Process Exhaust Ventilation System are summarized in Table 3-12.

Environmental Controls

All environmental consequences evaluated for the Liquid Waste Discard process do not exceed action levels specified in 10 CFR 70.61. All postulated accident scenarios were determined to be low consequence events and no environmental controls have been identified as items relied on for safety (IROFS). However, the following environmental controls reduce the potential impact to the environment.

The environmental controls for the Process Exhaust Ventilation System are summarized in Table 3-12.

Table 3-12
Hazard Summary for Process Exhaust Ventilation System

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	Uranium particulate accumulation on HEPA filter Uranium particulate and solution accumulation in ductwork Uranium accumulation in the scrubber or scrubber solution Uranium accumulation in the blowdown tank solution High concentration U sent to WWTF	HEPA filtration at all ventilation source points that may contain particulate U Siphon breaks to drain columns Condensate drain columns in ductwork	None	Periodic NDA scanning of ventilation ductwork, blowdown tank and scrubber for U accumulation Dual independent sampling of scrubber solution during process operations and of blowdown tank solution prior to WWTF transfer Monitoring of HEPA filter differential pressure
Chemical	None	Materials of construction Scrubber caustic feed tank overflow	Spring valve isolation for bulk nitric acid supply	Shut upstream isolation valves after nitric acid fill Discharge line capped
Radiological	Process scrubber solution Loss of process exhaust ventilation resulting in worker exposure	Separation of HEU material process area	Rad. Prot. Prog. monitoring and instruments	Personnel training and approved procedures Radiation protection program controls
Fire and Explosion	None	None	None	None
Environmental	Sodium Hydroxide Spill Nitric Oxide Vapor Release Norpar spill TBP spill Nitric Acid spill Unmitigated Gaseous Effluent Scrubber Solution Spill POG Condensation Spill	Materials of construction	Process Interlocks	Procedures and training

4.0 COMPLIANCE WITH 10 CFR 70.61

This section demonstrates how the ISA complies with the consequence and risk assessment requirements of 10 CFR 70.61. Part 70.61 requires that all credible accidents potentially affecting BPF operations that could result in significant chemical, radiological, fire, criticality, or environmental consequences be evaluated to determine those that would result in High or Intermediate consequences as defined in 70.61(a) and (b) (see Section 7 tables). Once the high and intermediate consequence events are identified, it must be shown that the High consequence events are Highly Unlikely, and the Intermediate consequence events are Unlikely after taking credit for implementation of designated IROFS. This determination requires a detailed Risk Assessment of each accident scenario, including assignment of failure indexes to credited engineered and administrative controls. Once the acceptable set of controls are defined, management measures are identified to ensure that the credited controls are available and reliable to perform their required function when needed.

4.1 ISA METHODOLOGY

The methodology for performing the ISA; including hazard analysis, consequence assessment, and risk assessment are defined in Section 5.2 of this report.

4.2 HAZARD EVALUATIONS, ACCIDENT SEQUENCES, AND CONSEQUENCE CALCULATIONS

As described in Section 5.2, the ISA Team performed a Process Hazards Analysis (PHA) for each process defined in Section 3 (U Metal, U Aluminum, Solvent Extraction, Downblending, Liquid Waste Discard and Process Exhaust Ventilation). In performing the PHA, the team evaluated all credible system and component failures based on Piping and Instrumentation Diagram (P&ID) drawings. Each type of failure was given an accident sequence number, and the team then determined the potential for criticality, chemical, radiological, fire or environmental consequences assuming no mitigation by passive, active, or administrative controls. All accident scenarios with potential criticality, chemical, radiological, fire, or environmental consequences were grouped together by consequence category for the responsible safety discipline to evaluate (Criticality Safety, Chemical Safety, Radiological Safety, Fire Safety and Environmental Safety). The responsible safety discipline then performed detailed consequence analyses to determine the events that exceed 10 CFR 70.61 exposure criteria for High or Intermediate level events. The consequence exposure criteria are defined in Section 7 of this report.

4.2.1 Criticality Safety Consequence Analysis

Criticality Safety accidents are evaluated and documented in Nuclear Criticality Safety Evaluations (NCSEs). The NCSEs are prepared based on the double

contingency principle in accordance with NFS procedures and ANSI standards. The double contingency principle is used to ensure that a criticality will not occur unless two unlikely, independent, concurrent changes occur in process conditions. In addition to the double contingency analysis, the NCSEs considered all credible component failures determined by the What-if hazards analysis. The criticality scenarios considered credible for the BPF processes are summarized in Table 4-9 along with the criticality risk assessment results. For all credible criticality scenarios, IROFS are defined and risk indexed to ensure that a criticality is highly unlikely as documented in Table 4-9.

NCSE documents were prepared for the following areas of the BPF:

Liquid Waste Discards
High Security Storage Area (UA1)
UA1 Dissolution
Solvent Extraction
Uranium Metal Dissolution
Downblending
Ventilation
Uranium Metal Sampling

4.2.2 Chemical Safety Consequence Analysis (Worker)

Consequence evaluations for employee Chemical Exposures were performed for the identified what-if scenarios. The consequence evaluations were intended as a method of identifying potential events which could result in a High or Intermediate level consequence as defined by 10 CFR 70.61. A high level consequence is identified in Part 70 as an acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed material that:

- Could endanger the life of a worker, or
- Could lead to irreversible or other serious, long-lasting health effects to any individual located outside the controlled area.

Intermediate consequences were defined as events that were not high consequence events that:

- Could lead to irreversible or other serious, long-lasting health effects to a worker, or
- Could cause mild transient health effects to any individual located outside the controlled area.

Various regulatory and industry consensus standards could be utilized for these consequence limits. Chapter 3 of NUREG-1520, "Standard Review Plan (SRP) for the Review of a License Application for a Fuel Cycle Facility" lists Emergency Response Planning Guidelines (ERPGs), Acute Exposure Guideline

Levels (AEGLs), and exposure limits established by the Occupational Safety and Health Administration (OSHA) to be acceptable. OSHA publishes 8 hour time weighted Permissible Exposure Limits, NIOSH publishes Immediately Dangerous to Life and Health (IDLH) limits, and ACGIH publishes 8 hour Threshold Limit Values and ERPGs. At present, only a relatively small number of chemicals have established ERPG levels. As a temporary interim measure, the Department of Energy (DOE) has published Temporary Emergency Exposure Guidelines (TEELs), using an established criteria outlined in "Derivation of Temporary Emergency Exposure Levels (TEELs)." TEELs are intended to be updated to reflect new ERPG limits as they are established. The consequence evaluations for employee Chemical Exposures utilized TEELs as consequence action levels where no ERPG level existed or where the TEEL reflects the established ERPG. Section 7 of this ISA Summary defines the TEEL values used to establish High and Intermediate levels for BPF chemicals.

Consequences were evaluated using computer modeling or hand calculations, as appropriate to the scenario. Computer models included CAMEO and ALOHA models, where applicable. Neither model is appropriate for inside spills, calculations close to the spill area, chemical mixtures or chemical solutions. ALOHA may be used for outside spills where appropriate.

General Assumptions for outside spills evaluated using hand calculations include:

- Total loss of contents of chemical source, unless otherwise stated in scenario specific information. Total loss of contents is considered to be the capacity of the tank or column.
- Assume pool size as estimated by the TEMA method taken from ARCHIE software and referenced in the Handbook of Chemical Hazard Analysis Procedures, published by the Federal Emergency Management Agency, the U.S. Department of Transportation, and the U.S. Environmental Protection Agency. Alternately, the analyst may assume a one centimeter spill depth, as outlined in EPA 550-B-99-009, Risk Management Program Guidance for Offsite Consequence Analysis.
- Assume unmitigated spill.
- Assume 5 minute exposure to liquid pool consisting of total loss of contents of source, unless otherwise specified. Vaporization rate was determined by using the Vaporization Model cited in EPA 560/4-88-002, Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form.
- Assume outside wind speed of 2.5 miles per hour.
- Assume no credit for operator intervention, procedural spill clean up instructions, or respiratory protection in initial consequence evaluation.
- Assume outside temperature of 90°F, unless higher operating temperature is stated in scenario specific information.
- Assume vapor pressure and specific gravity as listed in approved reference (Material Safety Data Sheet, Perry's Chemical Engineers Handbook, or engineering calculation based on approved reference).

- Assume tank or column size as indicated on P&IDs unless otherwise specified by engineering documentation
- Where established limits are for materials in solid form, and consequence evaluation is performed for materials in liquid form, scenario write-up will reflect that established limit is not appropriate. Where the scenario assumes a mode of force resulting in an airborne release of dissolved solids, the calculation will be based on the five-factor formula defined in NUREG/CR-6410 and supplemented as necessary with guidance provided in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities.*

For spill scenarios inside buildings, consequences will be evaluated using hand calculations. General Assumptions for inside spills include:

- Total loss of contents of chemical source, unless otherwise stated in scenario specific information. Total loss of contents is considered to be the capacity of the tank or column.
- Where columns exist in a bank, are valved together, and are indicated as normally open on the P&ID, loss of bank contents will be assumed unless otherwise stated in scenario specific information.
- Assume pool size as estimated by the TEMA method taken from ARCHIE software and referenced in the Handbook of Chemical Hazard Analysis Procedures, published by the Federal Emergency Management Agency, the U.S. Department of Transportation, and the U.S. Environmental Protection Agency. Alternately, the analyst may assume a one centimeter spill depth, as outlined in EPA 550-B-99-009, Risk Management Program Guidance for Offsite Consequence Analysis.
- Assume unmitigated spill.
- Assume 5 minute exposure to liquid pool consisting of total loss of contents of source, unless otherwise specified. Vaporization rate is determined by using the Vaporization Model cited in EPA 560/4-88-002, Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form.
- Assume inside wind speed of 0.5 miles per hour, otherwise no credit taken for makeup ventilation, unless otherwise specified (for example, in Nitrogen line break scenario).
- Assume no credit for operator intervention, procedural spill clean up instructions, or respiratory protection in initial consequence evaluation.
- Assume inside temperature of 70°F, unless higher operating temperature is stated in scenario specific information.
- Assume vapor pressure and specific gravity as listed in approved reference (Material Safety Data Sheet, Perry's Chemical Engineers; Handbook, or engineering calculation based on approved reference).
- Assume building volume as listed on P&IDs or engineering information.
- Assume tank or column size as indicated on P&IDs unless otherwise specified (with engineering documentation provided).

- Where established limits are for materials in solid form, and consequence evaluation is performed for materials in liquid form, scenario write up will reflect that established limit is not appropriate. Where the scenario assumes a mode of force resulting in an airborne release of dissolved solids, the calculation will be based on the five-factor formula defined in NUREG/CR-6410 and supplemented as necessary with guidance provided in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*.

Chemical Toxicity (Soluble Uranium)

The accident scenarios for evaluation are provided on tables developed by a qualified ISA team during a Process Hazard Analysis (PHA). Multiple types of consequences can result from the same event (item number), therefore the analysis is conducted for the most severe consequence for each item number. Upon completion of the analysis, each credible accident scenario is assigned an unmitigated, uncontrolled consequence severity category based on 10 CFR 70.61 as shown below:

- A high consequence as defined by 10 CFR 70.61 is one that results in an acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed material that could endanger the life of the worker. NUREG/CR-6410, section 5.8.3.1, *Exposure to Soluble Uranium* specifies that the threshold level, as referenced in NUREG-1391, to cause permanent renal damage to a 70-kg (154 lb) individual by inhalation is 40 mg soluble uranium due to chemical damage. While this intake would be limited to irreversible or serious long-lasting health effects and not life endangerment, it is protective for use as an intake level for high consequences. Therefore, events that result in a worker acute intake of 40 mg or more of soluble uranium are designated as high consequence.

- An intermediate consequence as defined by 10 CFR 70.61 is one that results in an acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed material that could lead to irreversible or other serious, long-lasting health effects to a worker. A 30 mg intake is specified in 10 CFR 70.61 as a high consequence for soluble uranium intake to an individual located outside the controlled area based on the individual developing irreversible or other serious long-lasting health effects. As documented in DOE-STD-1136-2000, *Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities* (Table 5-13) and ANSI/HPS N13.22-1995, *Bioassay Programs for Uranium - An American National Standard*, an acute intake of ≥ 30 mg of soluble uranium could result in renal damage, an irreversible, or serious long-lasting health effect. While not identical to the 40 mg threshold for similar effects given in NUREG/CR-6410, the 30 mg threshold is consistent and protectively lower. Therefore,

events that result in a worker intake of less than 40 mg but ≥ 30 mg are designated as intermediate consequence.

Methodology

The uranium intake for the worker is calculated as part of the Radiological Consequences; however, the results of the calculations and the associated controls are discussed in the Chemical Consequences. Further, for purposes of chemical evaluations, only soluble classes of uranium (class D and W) are considered and to remain consistent with the chemical toxicity calculations, the exposure duration is assumed to be 5 minutes. The total worker soluble uranium intake is estimated using the calculated uranium airborne concentration, the volume of air inhaled based on 10 CFR 20, Appendix B reference man inhalation rate of 2E+04 ml/min, and a five minute exposure time, divided by the specific activity of the uranium nuclide. The total uranium intake is the sum of the intakes for the individual uranium nuclides. The worker uranium intake ($I_{U\text{-}Occ}$) is calculated using the following equation:

$$I_{U\text{-}Occ} = \frac{ST_{Air} * F_{Inh} * t_E * K}{V_F}$$

where:

ST_{Air} = Airborne Source Term (g)
F_{Inh} = Inhalation Rate (ml/min)
t_E = Exposure Duration (5 min)
V_F = Dispersion Volume (m^3)
K = Unit Conversion Factor (1E-6 m^3/ml * 1000 mg/g)

Table 4-1
Chemical Safety Consequence Analysis Summary (Worker)

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		U Metal Dissolution	
1	Spill; Loss of Contents of Bulk Nitric Acid Supply Tank; capacity: [redacted] gallons	1UMD (1.4, 1.7, 1.139) 2UMD (2.4, 2.7, 2.139)	High
2	Spill; Loss of Contents of Column 3A11/3B11; capacity 17 liters Nitric Acid	1UMD (1.8, 1.13, 1.17, 1.141) 2UMD (2.8, 2.13, 2.17, 2.141)	Low
3	Spill; Limited to Loss of Residual Nitric Acid in Line	1UMD (1.18, 1.14) 2UMD (2.18, 2.14)	Low
4	Spill; Loss of contents of Hydrogen Peroxide Supply; capacity 55 gallons	1UMD (1.143, 1.144) 2UMD (2.143, 2.144)	Low
5	Spill; Loss of Contents of Column 3A12/3B12; capacity 2.5 liters Hydrogen Peroxide	1UMD (1.23, 1.26, 1.27, 1.30, 1.34, 1.145) 2UMD (2.23, 2.26, 2.27, 2.30, 2.34, 2.145)	Low
6	Spill; Limited to Loss of Residual Hydrogen Peroxide in Line	1UMD (1.31, 1.35, 1.36) 2UMD (2.31, 2.35, 2.36)	Low
7	Failure of Nitrogen Line; Nitrogen Release into Building	1UMD (1.47) 2UMD (2.47	Low
8	Spill; Loss of Dissolver Contents or Vapor Exposure; Loss of Containment through Vent or Enclosure failure	1UMD (1.1, 1.19, 1.44, 1.47, 1.48, 1.50, 1.53, 1.56, 1.59, 1.62, 1.63, 1.64, 1.65, 1.67, 1.68, 1.71, 1.73, 1.74, 1.76, 1.79, 1.80, 1.82, 1.86, 1.87, 1.106, 1.107, 1.109, 1.111, 1.113, 1.114, 1.116, 1.120, 1.124, 1.128, 1.134, 1.135, 1.136, 1.137, 1.138, 1.147, 1.148, 1.150, 1.152, 1.154, 1.156, 1.158, 1.162, 1.164, 1.182) 2UMD (2.1, 2.19, 2.44, 2.47, 2.48, 2.50, 2.53, 2.56, 2.59, 2.62, 2.63, 2.64, 2.65, 2.67, 2.68, 2.71, 2.73, 2.74, 2.76, 2.79, 2.80, 2.82, 2.86, 2.87, 2.106, 2.107, 2.109, 2.111, 2.113, 2.114, 2.116, 2.120, 2.124, 2.128, 2.134, 2.135, 2.136, 2.137, 2.138, 2.147, 2.148, 2.150, 2.152, 2.154, 2.156, 2.158, 2.162, 2.164, 2.182)	Low
9	Potential Fire in Enclosure	1UMD (1.164) 2UMD (2.164)	No Chemical Consequences Identified

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
*	NOx Release to Environment Addressed in Environmental Consequence Assessments	1 UMD (1.30, 1.34, 1.37, 1.39, 1.41, 1.46, 1.146) 2 UMD (2.30, 2.34, 2.37, 2.39, 2.41, 2.46, 2.146)	Addressed in Environmental Consequence Evaluations
**	Release of Oxidized U Metal Addressed in Soluble U ACE	1 UMD (1.149) 2 UMD (2.149)	Addressed in Soluble U ACE
***	Potential Fire or Explosion in Furnace	1 UMD (1.67, 1.73, 1.79, 1.82, 1.109, 1.156) 2 UMD (2.67, 2.73, 2.79, 2.82, 2.109, 2.156)	Deemed Not Credible in Fire Protection ACE
U Metal Oxidation and Dissolution (Sheet 3)			
1	Loss of Column, potential employee exposure to nitric acid due to a spill, overflow, line break, valve failure, etc. (bounding)	3DT (3.1, 3.2, 3.3, 3.10, 3.11, 3.13, 3.14, 3.18, 3.19, 3.20, 3.21, 3.23, 3.24, 3.25, 3.33, 3.36, 3.37, 3.43, 3.46, 3.47, 3.49, 3.50, 3.52, 3.53, 3.59)	Low
2	Release of Nitrogen into Work Area due to a line break	3DT (3.13)	Low
U Metal Oxidation and Dissolution (Sheet 4)			
1	Loss of Column, potential employee exposure to nitric acid due to a spill, overflow, line break, valve failure, etc. (bounding)	7DT (4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.14, 4.16, 4.17, 4.19, 4.20, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33, 4.35, 4.36, 4.37, 4.41, 4.45, 4.47, 4.48, 4.49, 4.53)	Low
2	Release of Nitrogen into Work Area due to a line break	7DT (4.19)	Low
U Metal Sampling			
1	Release of Argon into Work Area due to a line break or enclosure failure	UMS (39.13, 13.15, 39.16, 39.17)	Low
2	Potential Flash Fire, Potential Fire in Glovebox	UMS (39.13, 39.16)	No Chemical Consequence Identified

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		U Aluminum Dissolution	
1	Spill of caustic solution; potential employee exposure to sodium hydroxide, sodium nitrate, and barium nitrate in solution due to a spill, overflow, line break, valve failure, etc. (bounding). Calculation performed for 120 liters, assuming pump rate of 1 liter per minute over 1 hour	1UALD (29.20) 2UALD (30.20) 3UALD (31.20) 4UALD (32.20)	Low
2	Loss of Dissolver contents. Potential exposure to vapors from sodium hydroxide, sodium nitrate, and barium nitrate due to spill, overflow, line break, valve failure, etc. Potential for exposure to ammonia vapors during dissolution	1UALD (29.16, 29.22, 29.23, 29.25, 29.27) 2UALD (30.16, 30.22, 30.23, 30.25, 30.27) 3UALD (31.16, 31.22, 31.23, 31.25, 31.27) 4UALD (32.16, 32.22, 32.23, 32.25, 32.27)	Low
3	Loss of Dissolver contents, potential exposure to sodium hydroxide, sodium nitrate and barium nitrate due to spill, overflow, line break, valve failure, etc	1UALD (29.31, 29.33, 29.45, 29.48, 29.49, 29.60, 29.76, 29.77, 29.78, 29.80, 29.84, 29.88, 29.89, 29.91) 2UALD (30.31, 30.33, 30.45, 30.48, 30.49, 30.60, 30.76, 30.77, 30.78, 30.80, 30.84, 30.88, 30.89, 30.91) 3UALD (31.31, 31.33, 31.45, 31.48, 31.49, 31.60, 31.76, 31.77, 31.78, 31.80, 31.84, 31.88, 31.89, 31.91) 4UALD (32.31, 32.33, 32.45, 32.48, 32.49, 32.60, 32.76, 32.77, 32.78, 32.80, 32.84, 32.88, 32.89, 32.91)	Low
4	Release of sodium hydroxide, sodium nitrate, and barium nitrate vapors due to enclosure failure, breach of dissolver, POG or WOG line, or adverse chemical reaction due to incompatables	1UALD (29.26, 29.30, 29.35, 29.63, 29.64, 29.66, 29.68, 29.70) 2UALD (30.26, 30.30, 30.35, 30.63, 30.64, 30.66, 30.68, 30.70) 3UALD (31.26, 31.30, 31.35, 31.63, 31.64, 31.66, 31.68, 31.70) 4UALD (32.26, 32.30, 32.35, 32.63, 32.64, 32.66, 32.68, 32.70)	No Significant Exposure Expected
5	Release of Nitrogen into Work Area due to line break	1UALD (29.24, 29.30) 2UALD (30.24, 30.30) 3UALD (31.24, 31.30) 4UALD (32.24, 32.30)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
6	Employee Injury due to air line break	1UALD (29.38) 2UALD (30.38) 3UALD (31.38) 4UALD (32.38)	Not classified
7	Potential for loss of inert atmosphere resulting in potential explosion	1UALD (29.23; 29.25; 29.26; 29.30; 29.78; 29.80; 29.88) 2UALD (30.23; 30.25; 30.26; 30.30; 30.78; 30.80; 30.88) 3UALD (31.23; 31.25; 31.26; 31.30; 31.78; 31.80; 31.88) 4UALD (32.23; 32.25; 32.26; 32.30; 32.78; 32.80; 32.88)	Intermediate
8	Potential explosion due to vented Hydrogen	1UALD (29.45; 29.48; 29.49; 29.66; 29.70; 29.84) 2UALD (30.45; 30.48; 30.49; 30.66; 30.70; 30.84) 3UALD (31.45; 31.48; 31.49; 31.66; 31.70; 31.84) 4UALD (32.45; 32.48; 32.49; 32.66; 32.70; 32.84)	High
***	Potential explosion due to vented hydrogen into POG; Potential Loss of inert atmosphere	1UALD (29.16; 29.76) 2UALD (30.16; 30.76) 3UALD (31.16; 31.76) 4UALD (32.16; 32.76)	Identified in Fire Protection ACE as No Safety Concern as a Single Failure Event
***	Potential Explosion due to vented hydrogen in room or hydrogen build up	1UALD (29.31; 29.35; 29.63; 29.64; 29.68) 2UALD (30.31; 30.35; 30.63; 30.64; 30.68) 3UALD (31.31; 31.35; 31.63; 31.64; 31.68) 4UALD (32.31; 32.35; 32.63; 32.64; 32.68)	Identified in Fire Protection ACE as Not Credible
***	Potential explosion	1UALD (29.33) 2UALD (30.33) 3UALD (31.33) 4UALD (32.33)	Identified in Fire Protection ACE as Not Credible
		U Aluminum Separation (Sheets 1 and 2)	
1	Chemical Vapor due to overheating failure of WOG or POG integrity valve failure, potential exposure to sodium hydroxide, sodium nitrate, and barium nitrate, or nitric acid vapor	1UALS (33.1; 33.3; 33.5; 33.7; 33.12; 33.13; 33.104) 2UALS (34.1; 34.3; 34.5; 34.7; 34.12; 34.13; 34.102)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
2	Loss of Dissolver [; potential exposure to vapors from sodium hydroxide, sodium nitrate, and barium nitrate, nitric acid in solution due to a spill, overflow, line break, valve failure, etc]	1UALS (33.10, 33.14, 33.16, 33.19, 33.21, 33.29, 33.66, 33.69, 33.71, 33.74, 33.75, 33.77, 33.87, 33.89, 33.90, 33.95, 33.97, 33.109) 2UALS (34.10, 34.14, 34.16, 34.19, 34.21, 34.29, 34.59, 34.62, 34.64, 34.67, 34.68, 34.70, 34.80, 34.82, 34.83, 34.88, 34.90, 34.107)	Low
3	Loss of Centrifuge [contents,] [potential exposure to sodium hydroxide, sodium nitrate, and barium nitrate due to spill, overflow, line break, valve failure, etc]	1UALS (33.24) 2UALS (34.24)	Low
4	Loss of Dissolver [contents,] [potential exposure to sodium hydroxide, sodium nitrate, and barium nitrate due to spill, overflow, line break, valve failure, etc]	1UALS (33.27, 33.28, 33.108) 2UALS (34.27, 34.28, 34.106)	Low
5	Loss of Column [contents,] [potential exposure to sodium hydroxide, sodium nitrate, and barium nitrate due to spill, overflow, line break, valve failure, etc]	1UALS (33.33, 33.34, 33.35, 33.36, 33.37, 33.39, 33.40, 33.41, 33.42, 33.43, 33.45, 33.46, 33.47, 33.48, 33.49, 33.50, 33.51, 33.97, 33.107) 2UALS (34.33, 34.34, 33.35, 34.36, 34.37, 34.39, 34.40, 34.41, 34.42, 34.43, 34.45, 34.46, 34.47, 34.48, 34.49, 34.50, 34.51, 34.90, 34.105)	Low
6	Loss of contents, Bulk Nitric Acid Tank, 67%, capacity [redacted] gallons] [potential exposure to nitric acid due to a spill, overflow, line break, valve failure, etc]	1UALS (33.55, 33.98) 2UALS (34.52, 34.91)	High
7	Loss of Column [contents, Nitric Acid, 67%,] [due to a spill, overflow, line break, valve failure, etc]	1UALS (33.54, 33.60, 33.61, 33.62, 33.64) 2UALS (34.53, 34.54, 34.55, 34.57, 34.93, 34.96)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
8	Release of Nitrogen into Work Area due to a line break	1UALS (33.77) 2UALS (34.70)	Low
***	Potential fire due to pyrophoric dry UO2 formation in centrifuge	1UALS (33.24) 2UALS (34.24)	Identified in Fire Protection ACE as Not Credible
U Aluminum Dissolution Caustic Discard Columns, Bank A and B			
1	Loss of Column contents, [redacted] potential exposure to sodium hydroxide, sodium nitrate and barium nitrate due to spill, overflow, line break, valve failure, etc.	1UALC (35.3, 35.9, 35.12, 35.13, 35.14, 35.16, 35.19, 35.20, 35.21, 35.25, 35.34, 35.40, 35.41, 35.42, 35.44, 35.48, 35.51, 35.59) 2UALC (36.3, 36.9, 36.12, 36.13, 36.14, 36.16, 36.17, 36.19, 36.20, 36.21, 36.25, 36.34, 36.40, 36.41, 36.42, 36.48, 36.51, 36.59)	Low
2	Loss of Column contents due to overflow or valve failure, potential exposure to vapors from sodium hydroxide, sodium nitrate, and barium nitrate	1UALC (35.7, 35.8, 35.36) 2UALC (36.7, 36.8, 36.36)	Low
3	Release of Nitrogen into Work Area due to a line break	1UALC (35.13) 2UALC (36.13)	Low
4	Employee Injury due to air line break	1UALC (35.33) 2UALC (36.33)	Not classified
U Aluminum Dissolution Accountability Columns			
1	Loss of Column contents, [redacted] potential exposure to nitric acid due to a spill, overflow, line break, valve failure, etc.	UALAC (37.3, 37.6, 37.9, 37.10, 37.11, 37.13, 37.16, 37.17, 37.18, 37.38, 37.42, 37.46)	Low
2	Loss of Column contents from P&ID F0411.D and F0410.D, potential exposure to nitric acid due to spill or line break, etc.	UALAC (37.5, 37.28, 37.29)	Low
3	Release of Nitrogen into Work Area due to a line break	UALAC (37.10)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
4	Release of Nitric Acid Vapors into Work Area due to an enclosure failure	UALAC (37.33)	Low
5	Release of Nitric Acid Vapors into Work Area due to a plug of the POG	UALAC (37.36)	Low
6	Release of Nitric Acid Vapors into Work Area due to a breech of the POG	UALAC (37.37, 37.39, 37.40)	Low
Caustic Make-up and Storage Tanks Located Outside Building 333			
1	Sodium Hydroxide Bulk Tank, 30% solution, Overflow. Calculations assume a 1 centimeter spill depth	CMST (38.1, 38.30)	Intermediate
2	Uncontrolled vent to atmosphere from Tank 1K01	CMST (38.3)	No Significant Exposure Expected
3	Tank 1K01 (Sodium Nitrate, Barium Nitrate) tank failure. Calculations assume a 1 centimeter spill depth	CMST (38.5)	Intermediate
4	Tank 1K02 (Sodium Hydroxide) tank failure. Calculations assume a 1 centimeter spill depth	CMST (38.6)	Intermediate
5	Overflow of Tank 1K01 from Bulk Tanker Truck (sodium Nitrate, 40% solution and Barium Nitrate, 1.6%) Calculations assume a 1 centimeter spill depth	CMST (38.28, 38.39, 38.51)	Intermediate
6	Incompatible Materials in 1K01/1K02	CMST (38.9)	No Chemical Incompatibilities Identified
7	Spill from Tank 1K01. Spill calculated at pump rate of 1 liter per hour over 1 hour	CMST (38.14, 38.44)	Low
8	Spill from Tank 1K02. Spill calculated at pump rate of 1 liter per hour over 1 hour	CMST (38.14, 38.42)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
9	Loss of Residual in Line during Maintenace, Sodium Hydroxide	CMST (38.15, 38.46, 38.48)	Low
10	Loss of Residual in Line during Maintenance, Sodium Nitrate or Barium Nitrate	CMST (38.15, 38.46, 38.48)	Low
11	Overflow of Dissolvers in U Al with Sodium Hydroxide. Spill calculated at pump rate of 1 liter per hour over 1 hour	CMST (38.16, 38.17, 38.18, 38.19)	Low
12	Overflow of Dissolvers in U Al with Sodium Nitrate and Barium Nitrate Spill calculated at pump rate of 1 liter per hour over 1 hour	CMST (38.16, 38.17, 38.18, 38.19)	Low
13	Sodium Hydroxide Line Break Calculations assume a 1 centimeter spill depth	CMST (38.25)	Intermediate
14	Sodium Nitrate, Barium Nitrate Line Break. Calculations assume a 1 centimeter spill depth	CMST (38.26)	Intermediate
15	Sodium Nitrate Tanker Breach Calculations assume a 1 centimeter spill depth	CMST (38.52)	Intermediate
16	Potential for loss of inert atmosphere resulting in potential explosion in U Al	CMST (38.16, 38.17, 38.18, 38.19, 38.20, 38.31, 38.32, 38.33, 38.34, 38.36, 38.47)	Evaluated in Scenario 7 of U Al Dissolution Evaluation (Intermediate)
		Solvent Extraction Staging Columns	
1	Loss of contents, Bulk Nitric Acid Tank, 67%, assume capacity of 5700 gallons	SXFC (9.5, 9.15)	High
2	Loss of contents, Columns (U or solvent spill) Use to bound spill from U Al	SXFC (9.3, 9.9, 9.11, 9.13, 9.14, 9.21, 9.22, 9.25, 9.27, 9.28, 9.30, 9.31, 9.34, 9.37, 9.38, 9.44, 9.45, 9.46, 9.47, 9.50, 9.52, 9.53, 9.60, 9.62, 9.64, 9.65)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		Solvent Extraction – 1st Pass Raffinate Storage	
1	Loss of contents, Bulk Nitric Acid Tank, 67%, assume capacity of [redacted] gallons	1PRS (17.18, 17.21)	High
2	Loss of contents, [redacted] U or solvent spill	1PRS (17.3, 17.5, 17.9, 17.11, 17.14, 17.15, 17.19, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.32, 17.33, 17.34, 17.45, 17.47, 17.51, 17.57, 17.61, 17.62, 17.65, 17.76, 17.77, 17.79, 17.82, 17.83, 17.85)	Low
***	Potential Fire	1PRS (17.3, 17.5, 17.9, 17.11, 17.19, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.33, 17.45, 17.47, 17.65)	Deemed Highly Unlikely in Fire Protection ACE
		Solvent Extraction – 2nd Pass Raffinate Storage	
1	Loss of contents, Bulk Nitric Acid Tank, 67%, assume capacity of 5700 gallons	2PRS (18.8)	High
2	Loss of contents, [redacted] Vapor Release (18.27)	2PRS (18.2, 18.9, 18.11, 18.12, 18.14, 18.16, 18.17, 18.18, 18.19, 18.22, 18.26, 18.27, 18.29, 18.30, 18.33, 18.34, 18.35)	Low
***	Potential Fire	2PRS (18.2, 18.9, 18.11, 18.12, 18.14, 18.16, 18.18, 18.22, 18.29, 18.33)	Deemed Highly Unlikely in Fire Protection ACE
		Solvent Extraction Chemical Makeup Area (Sheet 1)	
1	Loss of Contents, Bulk Nitric Acid Tank, 67%, capacity [redacted] gallons	1SXCM (23.4, 23.6)	High
2	Loss of Contents, Tank 2L09, Nitric Acid, 67%, [redacted]	1SXCM (23.67, 23.69, 23.70, 23.71, 23.72, 23.79, 23.80, 23.83, 23.86)	Low
3	Loss of contents, Bulk Petroleum, capacity 55 gallons	1SXCM (23.7, 23.8, 23.82)	Low
4	Loss of Contents, Bulk TBP, capacity 55 gallons	1SXCM (23.7, 23.8, 23.82)	Low
5	Loss of Contents, Tank 2L01, Petroleum, [redacted]	1SXCM (23.9, 23.10, 23.12, 23.13, 23.18, 23.19, 23.20, 23.22)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
6	Loss of Contents, Tank 2L03 Solvent, Calculations for total in system	1SXCM (23.24, 23.26, 23.27, 23.34, 23.36, 23.37, 23.38, 23.39, 23.40, 23.41, 23.42, 23.86)	Low
7	Loss of contents, Tank 2L05, 5% Sodium Carbonate,	1SXCM (23.1, 23.44, 23.48, 23.51, 23.53, 23.54, 23.55, 23.58, 23.61, 23.62, 23.75, 23.86, 23.88)	Low
8	Incompatible Materials in Tank 2L01/2L03	1SXCM (23.9)	No Adverse Chemical Reactions Identified
9	Vapor Release Into Work Area	1SXCM (23.80, 23.85, 23.87)	Low
10	Incompatible Materials in Tank 2L05	1SXCM (23.75)	No Adverse Chemical Reactions Identified
11	Incompatible Materials in Tank 2L09	1SXCM (23.83)	No Incompatible Materials Identified
***	Potential Fire Involving Solvent Spill	1SXCM (23.7, 23.8, 23.10, 23.12, 23.13, 23.18, 23.19, 23.20, 23.22, 23.24, 23.26, 23.27, 23.34, 23.36, 23.37, 23.38, 23.39, 23.40, 23.41, 23.42, 23.55, 23.82, 23.86)	Deemed Highly Unlikely in Fire Protection ACE
		Solvent Extraction Chemical Makeup Area (Sheet 2)	
1	Loss of Contents, Tank 2L09, Nitric Acid, 67%,	2SXCM (24.7, 24.8, 24.52)	Low
2	Loss of Contents, Tank 2D11, 0.5 M Nitric Acid,	2SXCM (24.1, 24.10, 24.14, 24.16, 24.18, 24.20, 24.22, 24.27, 24.28, 24.29, 24.32, 24.38, 24.50, 24.53, 24.54)	Low
3	Incompatible Materials added to Tank 2D11	2SXCM (24.9)	No Incompatible Material Addition Identified

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
***	Potential Fire in SX due to Nitric Acid into Solvent	2SXCM (24.2; 24.7; 24.52)	Deemed No Safety Concern in Fire Protection ACE
		Evaporator Condensate Columns Set A/B	
1	Loss of contents; [redacted] assume 3M Nitric Acid content	ECA (20.2; 20.4; 20.5; 20.7; 20.8; 20.10; 20.11; 20.17; 20.31; 20.32; 20.40; 20.41; 20.43) ECB (21.1; 21.3; 21.4; 21.6; 21.7; 21.13; 21.27; 21.28; 21.36; 21.37; 21.39)	Low
2	Steam Release; Employee Injury	ECA (20.1)	Not Classified
***	Potential Fire	ECA (20.17) ECB (20.13)	Deemed Highly Unlikely in Fire Protection ACE
		1st Pass Evaporator	
1	Loss of contents; Bulk Nitric Acid Tank; 67%; capacity of [redacted] gallons	1PE (12.43; 12.45; 12.47)	High
2	Loss of contents; Column 2011; [redacted] Assume Nitric Acid Molarity of 3	1PE (12.24; 12.30; 12.32; 12.52; 12.55; 12.59; 12.60; 12.61; 12.62; 12.63; 12.64; 12.65; 12.66; 12.67; 12.68; 12.69; 12.70; 12.72)	Low
3	Nitrogen Line break	1PE (12.56)	Low
4	Loss of contents; [redacted] Assume Nitric Acid Molarity of 3	1PE (12.26; 12.30; 12.32; 12.34; 12.52; 12.55; 12.56; 12.73; 12.74; 12.75; 12.79; 12.80; 12.81; 12.82; 12.83; 12.85; 12.88; 12.90; 12.92; 12.94; 12.95; 12.100; 12.102; 12.103; 12.106; 12.107; 12.108; 12.110; 12.113; 12.114; 12.115; 12.116; 12.117; 12.118; 12.120; 12.121; 12.122; 12.128; 12.130; 12.179; 12.185; 12.186; 12.187)	Low
5	Loss of contents; Column 2017; [redacted] Assume Nitric Acid Molarity of 3	1PE (12.30; 12.167)	Low
6	Vapor Release (includes NOx)	1PE (12.28; 12.89; 12.91; 12.94; 12.99; 12.132)	Low
7	Steam Release/Employee Burn	1PE (12.1; 12.7; 12.9; 12.10; 12.12; 12.19; 12.40; 12.79; 12.80; 12.81; 12.83; 12.89; 12.91; 12.100; 12.102; 12.103; 12.106; 12.107; 12.108; 12.110; 12.113; 12.114; 12.115; 12.116; 12.117; 12.118; 12.120; 12.121; 12.122; 12.138; 12.139; 12.141; 12.146; 12.152; 12.154; 12.157; 12.159; 12.164; 12.166; 12.167; 12.168; 12.169; 12.174; 12.176; 12.179)	Not Classified
8	Potential Red Oil Accident	1PE (12.88; 12.90; 12.92; 12.185; 12.186; 12.187)	Assumed High

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		1st /2nd Pass Solvent Wash	
1	Loss of contents; Tank 2L11; [0.5 M Nitric Acid]	1PSW (11:1) 2PSW (14:1)	Low
2	Loss of contents; Solvent content in SX 1st Pass System; [total capacity in 1st and 2nd Pass System]	1PSW (11:2, 11:3, 11:6, 11:10, 11:11, 11:12, 11:13, 11:14, 11:22, 11:24, 11:26, 11:27, 11:28, 11:30, 11:40, 11:41, 11:48, 11:49, 11:50, 11:51, 11:52, 11:53, 11:54, 11:55, 11:56, 11:57, 11:58, 11:59, 11:60, 11:61, 11:62, 11:63, 11:65, 11:67, 11:68, 11:69, 11:70, 11:71, 11:73, 11:74, 11:75, 11:77, 11:78, 11:79, 11:80, 11:82, 11:83, 11:84, 11:85, 11:90, 11:91, 11:92, 11:93, 11:94, 11:95, 11:99, 11:101, 11:102, 11:103, 11:106, 11:107, 11:112, 11:114, 11:116) 2PSW (14:2, 14:3, 14:6, 14:10, 14:11, 14:12, 14:13, 14:14, 14:22, 14:24, 14:25, 14:26, 14:27, 14:28, 14:30, 14:40, 14:41, 14:48, 14:49, 14:50, 14:51, 14:52, 14:53, 14:54, 14:55, 14:56, 14:57, 14:58, 14:59, 14:60, 14:61, 14:62, 14:63, 14:65, 14:67, 14:68, 14:69, 14:70, 14:71, 14:73, 14:74, 14:75, 14:77, 14:78, 14:79, 14:80, 14:82, 14:83, 14:84, 14:85, 14:90, 14:91, 14:92, 14:93, 14:94, 14:95, 14:99, 14:101, 14:102, 14:103, 14:106, 14:108, 14:110, 14:111, 14:116)	Low
3	Loss of contents; UN Solution in System; [ ] Assume Nitric Acid Molarity of 3]	1PSW (11:6, 11:10, 11:11, 11:12, 11:13, 11:14, 11:22, 11:24, 11:25, 11:26, 11:27, 11:28, 11:30, 11:40, 11:41, 11:48, 11:49, 11:50, 11:51, 11:52, 11:53, 11:54, 11:55, 11:56, 11:57, 11:58, 11:59, 11:60, 11:61, 11:62, 11:63, 11:65, 11:67, 11:68, 11:69, 11:70, 11:71, 11:73, 11:74, 11:75, 11:77, 11:78, 11:79, 11:80, 11:82, 11:83, 11:84, 11:85, 11:90, 11:91, 11:92, 11:93, 11:94, 11:95, 11:99, 11:101, 11:102, 11:103, 11:106, 11:107, 11:112, 11:114, 11:116) 2PSW (14:6, 14:10, 14:11, 14:12, 14:13, 14:14, 14:22, 14:24, 14:25, 14:26, 14:27, 14:28, 14:30, 14:40, 14:41, 14:48, 14:49, 14:50, 14:51, 14:52, 14:53, 14:54, 14:55, 14:56, 14:57, 14:58, 14:59, 14:60, 14:61, 14:62, 14:63, 14:65, 14:67, 14:68, 14:69, 14:70, 14:71, 14:73, 14:74, 14:75, 14:77, 14:78, 14:79, 14:80, 14:82, 14:83, 14:84, 14:85, 14:90, 14:91, 14:92, 14:93, 14:94, 14:95, 14:99, 14:101, 14:102, 14:103, 14:106, 14:108, 14:110, 14:111, 14:116)	Low
4	Loss of Contents; 5% Sodium Carbonate from Tank 2L05;]	1PSW (11:8) 2PSW (14:8)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
***	Potential Fire	1PSW (11.6, 11.10, 11.11, 11.12, 11.13, 11.14, 11.22, 11.24, 11.28, 11.30, 11.40, 11.41, 11.48, 11.49, 11.50, 11.51, 11.52, 11.53, 11.54, 11.55, 11.56, 11.58, 11.60, 11.62, 11.65, 11.67, 11.68, 11.69, 11.70, 11.73, 11.74, 11.77, 11.78, 11.80, 11.82, 11.84, 11.85, 11.90, 11.106, 11.112, 11.114) 2PSW (14.6, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.28, 14.30, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.58, 14.60, 14.62, 14.65, 14.67, 14.68, 14.69, 14.70, 14.73, 14.74, 14.77, 14.78, 14.80, 14.82, 14.84, 14.85, 14.90, 14.106, 14.108, 14.110)	Deemed Highly Unlikely in Fire Protection ACE
***	Potential Fire	1PSW (11.2, 11.25, 11.26, 11.27, 11.91, 11.92, 11.94, 11.99, 11.101, 11.102, 11.103) 2PSW (14.2, 14.25, 14.26, 14.27, 14.91, 14.92, 14.94, 14.99, 14.101, 14.102, 14.103)	Deemed Highly Unlikely in Fire Protection ACE
		1st Pass Solvent Extraction	
1	Loss of contents, Tank 2L11, assume 0.5 M Nitric Acid	1PX (10.1)	Low
2	Loss of contents, Columns to SX, or RA Recyle input, Assume Nitric Acid Molarity of 3. Calculated for 520 liters	1PX (10.2, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.56, 10.58, 10.59, 10.60, 10.61, 10.62, 10.63, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.74, 10.75, 10.76, 10.77, 10.78, 10.80, 10.81, 10.82, 10.83, 10.84, 10.85, 10.86, 10.88, 10.89, 10.90, 10.91, 10.92, 10.94, 10.95, 10.96, 10.97, 10.98, 10.99, 10.100, 10.103, 10.104, 10.105, 10.106, 10.107, 10.108, 10.109, 10.110, 10.112, 10.119, 10.122, 10.124, 10.126, 10.129)	Low
3	Loss of contents, Solvent content in SX 1st Pass System, in 1st and 2nd Pass System	1PX (10.2, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.56, 10.58, 10.59, 10.60, 10.61, 10.62, 10.63, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.74, 10.75, 10.76, 10.77, 10.78, 10.80, 10.81, 10.82, 10.83, 10.84, 10.85, 10.86, 10.88, 10.89, 10.90, 10.91, 10.92, 10.94, 10.95, 10.96, 10.97, 10.98, 10.99, 10.100, 10.103, 10.104, 10.105, 10.106, 10.107, 10.108, 10.109, 10.110, 10.112, 10.116, 10.119, 10.122, 10.124, 10.126, 10.129)	Low
4	Red Oil Accident	1PX (10.2, 10.55, 10.57, 10.63)	Assumed High
***	Potential Fire	1PX (10.2, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.56, 10.58, 10.59, 10.60, 10.61, 10.62, 10.63, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.75, 10.77, 10.78, 10.80, 10.81, 10.83, 10.85, 10.86, 10.88, 10.89, 10.91, 10.94, 10.95, 10.96, 10.97, 10.99, 10.103, 10.104, 10.105, 10.107, 10.109, 10.110, 10.112, 10.116, 10.119, 10.122, 10.124, 10.126)	Deemed Highly Unlikely in Fire Protection ACE

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		Solvent Extraction Product Storage Columns	
1	Loss of contents; (assume 3M Nitric Acid Content - Vapor release (22.35))	SXPS (22.3, 22.5, 22.26, 22.28, 22.30, 22.32, 22.34, 22.35, 22.36, 22.38, 22.40, 22.41, 22.43, 22.45, 22.46, 22.47, 22.48, 22.49, 22.50, 22.51, 22.52, 22.53, 22.55, 22.59, 22.61, 22.63, 22.67, 22.70, 22.72, 22.74, 22.76)	Low
2	Nitrogen Release into Room	SXPS (22.7)	Low
		2nd Pass Evaporator	
1	Scenario 1 deleted; Nitric Acid line not present		
2	Loss of contents; Column 2P11 (Assume Nitric Acid Molarity of 3)	2PE (15.24, 15.26, 15.28, 15.30, 15.32, 15.47, 15.50, 15.54, 15.55, 15.56, 15.57, 15.58, 15.59, 15.60, 15.61, 15.62, 15.63, 15.64, 15.66, 15.155)	Low
3	Nitrogen Line break	2PE (15.51)	Low
4	Loss of contents; Column (Assume Nitric Acid Molarity of 3)	2PE (15.30, 15.32, 15.34, 15.47, 15.50, 15.51, 15.67, 15.68, 15.69, 15.73, 15.74, 15.75, 15.76, 15.77, 15.79, 15.82, 15.84, 15.86, 15.88, 15.89, 15.92, 15.94, 15.95, 15.96, 15.98, 15.99, 15.100, 15.102, 15.104, 15.153, 15.156, 15.157)	Low
5	Loss of contents; Column 2P17 (Assume Nitric Acid Molarity of 3)	2PE (15.30, 15.141)	Low
6	Vapor Release (includes NOx)	2PE (15.28, 15.83, 15.85, 15.91, 15.106)	Low
7	Steam Release/Employee Burn	2PE (15.1, 15.7, 15.9, 15.10, 15.12, 15.19, 15.40, 15.68, 15.73, 15.74, 15.75, 15.77, 15.83, 15.85, 15.92, 15.94, 15.95, 15.96, 15.98, 15.99, 15.100, 15.112, 15.113, 15.115, 15.120, 15.126, 15.128, 15.131, 15.133, 15.138, 15.140, 15.142, 15.143, 15.148, 15.150, 15.153)	Not classified
8	Potential Red Oil Accident	2PE (15.82, 15.84, 15.86, 15.155, 15.156, 15.157)	Assumed High
		2nd Pass Solvent Extraction	
1	Loss of contents; Tank 2B11; assume 0.5 M Nitric Acid	2PSX (13.1)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
2	Loss of contents; Columns to SX, or from concentrate hold column ( ); Assume Nitric Acid Molarity of 3	2PSX (13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.35, 13.36, 13.37, 13.38, 13.39, 13.40, 13.41, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.50, 13.51, 13.52, 13.53, 13.54, 13.56, 13.57, 13.58, 13.59, 13.60, 13.62, 13.63, 13.64, 13.65, 13.66, 13.67, 13.68, 13.69, 13.70, 13.71, 13.75, 13.77, 13.82, 13.84, 13.86, 13.89, 13.90, 13.91, 13.93)	Low
3	Loss of contents; Solvent content in SX 1st Pass System in 1st and 2nd Pass System	2PSX (13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.35, 13.36, 13.37, 13.38, 13.39, 13.40, 13.41, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.50, 13.51, 13.52, 13.53, 13.54, 13.56, 13.57, 13.58, 13.59, 13.60, 13.62, 13.63, 13.64, 13.65, 13.66, 13.67, 13.68, 13.69, 13.70, 13.71, 13.75, 13.77, 13.80, 13.82, 13.84, 13.86, 13.89, 13.90, 13.91, 13.93)	Low
4	Red Oil Accident	2PSX (13.35, 13.37, 13.41, 13.71, 13.90)	Assumed High
***	Potential Fire	2PSX (13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.35, 13.36, 13.38, 13.39, 13.40, 13.41, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.51, 13.53, 13.54, 13.56, 13.57, 13.59, 13.62, 13.63, 13.64, 13.65, 13.67, 13.69, 13.70, 13.72, 13.75, 13.77, 13.80, 13.82, 13.84, 13.89, 13.90, 13.91)	Deemed Highly Unlikely in Fire Protection ACE
		Interface Solids Filtering	
1	Loss of contents; Column 2101 assume 3 M Nitric Acid Content; Vapor Release included	SXSF (16.1, 16.9, 16.14, 16.15, 16.16, 16.19, 16.27, 16.28, 16.29, 16.31, 16.37, 16.39, 16.40, 16.41, 16.44, 16.45, 16.52, 16.55, 16.57, 16.59)	Low
2	Incompatible materials enter system	SXSF (16.31)	No Incompatible materials identified
		Solvent Extraction Sump Columns	
1	Loss of contents; Bulk Nitric Acid Tank, 67%, assume capacity of 5700 gallons	SXSC (19.8)	High
2	Loss of contents;	SXSC (19.5, 19.9, 19.11, 19.12, 19.14, 19.15, 19.20, 19.22)	Low
3	Loss of contents; Solvent content in System in 1st and 2nd Pass System	SXSC (19.5, 19.9, 19.11, 19.12, 19.14, 19.15, 19.20, 19.22)	Low
4	Vapor Release	SXSC (19.23)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
***	Potential Fire	SXSC (19.5, 19.9, 19.11, 19.12, 19.14, 19.20)	Deemed Highly Unlikely in Fire Protection ACE
		Downblending	
1	Loss of Contents, HEU Mix/Measure Columns,	UDB (5.3, 5.146, 5.147)	Low
2	Loss of Contents, Columns	UDB (5.5, 5.8, 5.13, 5.14, 5.16, 5.18, 5.20, 5.22, 5.24, 5.26, 5.28, 5.30, 5.32, 5.34, 5.44, 5.46, 5.47)	Low
3	Loss of Contents, Dissolution Tank 4D04,	UDB (5.52)	Low
4	Loss of Contents, Tank 4C02	UDB (5.54, 5.57, 5.140, 5.141)	Low
5	Loss of Contents, Tank 4C01	UDB (5.5, 5.55, 5.78, 5.80, 5.83, 5.84, 5.88, 5.91, 5.93, 5.94, 5.97, 5.100, 5.103, 5.116, 5.120, 5.129, 5.138, 5.139, 5.142, 5.143, 5.150)	Low
6	Loss of Contents, Dissolution Tank 4D04,	UDB (5.122, 5.128)	Low
		HEU Mix/Measure Columns	
1	Loss of contents, to knockout column from overflow or spill to floor,	UMM (8.1, 8.3, 8.5, 8.10, 8.12, 8.16, 8.17, 8.19, 8.20, 8.22, 8.23, 8.26, 8.32, 8.33, 8.35)	Low
2	Loss of contents, to SX Staging Columns to knockout column,	UMM (8.1, 8.5, 8.36)	Low
3	Loss of contents, from U Metal input line,	UMM (8.15)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
4	Loss of contents, from SX input line,	UMM (8.15)	Low
5	Nitrogen Supply line breaks; Nitrogen release into work area	UMM (8.16)	Low
		Natural Dissolution	
1	Loss of Contents; UO3 Drum capacity of [redacted] pounds gross weight assume spill inside LEU area	UND (6.1; 6.2; 6.3, 6.5; 6.6; 6.7; 6.8; 6.9; 6.10; 6.11; 6.12; 6.18; 6.20; 6.21; 6.25; 6.26; 6.32; 6.289)	Addressed in Soluble U ACE
2	Loss of Contents; Hopper 4D02 assume spill inside LEU area	UND (6.22; 6.23; 6.27; 6.29; 6.35)	Addressed in Soluble U ACE
3	Loss of Contents; Bulk Nitric Acid Tank, 67%, capacity of 5700 gallons	UND (6.39; 6.41; 6.43)	High
4	Loss of Contents; DI water, resulting in overflow of Tank 4D04;	UND (6.46; 6.158; 6.165; 6.172)	Low
5	Loss of Contents, Tank 4D04 assume spill inside LEU area;	UND (6.59; 6.60; 6.62; 6.64; 6.66; 6.69; 6.71; 6.72; 6.80; 6.81; 6.84; 6.100; 6.101; 6.102; 6.104; 6.106; 6.110; 6.176; 6.177; 6.179; 6.184; 6.186; 6.188; 6.189; 6.190; 6.193; 6.199; 6.211; 6.212; 6.221; 6.225; 6.227; 6.228; 6.235; 6.236; 6.237; 6.238; 6.241; 6.242; 6.243; 6.261; 6.265; 6.266; 6.268; 6.272; 6.273)	Low
6	Loss of Contents; Tank 4D04 assume spill inside LEU area; Assume nitric acid 67%, added before water	UND (6.63)	No significant employee exposure expected
7	Vapor Loss from Tank 4D04; Assume NOx release during processing	UND (6.68; 6.187; 6.196; 6.224, 6.226; 6.233; 6.246)	High
8	Loss of Contents; Vac-U-Max 55 gallon drum collection container; Spill inside LEU area	UND (6.280)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
9	Loss of Contents, Vac-U-Max 55 gallon drum collection container, Spill Outside	UND (6.281)	Low
10	Incompatible/Wrong Material in Vac-U-Max collection container	UND (6.283)	Low
***	Potential Dust Explosion Hazard, Potential Oxide Fire	UND (6.1, 6.2, 6.3, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11, 6.12, 6.18, 6.20, 6.21, 6.22, 6.23, 6.27, 6.29, 6.32, 6.35)	Deemed Not Credible in Fire Protection ACB
***	Potential Fire	UND (6.20, 6.21)	No additional equipment damage identified, No chemical consequences identified
		UN Transfer	
1	Loss of contents, UN Tank Trailer, Assume outside spill	UNT (7.3, 7.31, 7.39)	Low
2	Loss of contents, Tank 4E01, Assume spill in BEU area	UNT (7.5, 7.12, 7.13, 7.17, 7.19, 7.20, 7.22, 7.45, 7.50, 7.51, 7.68)	Low
3	Loss of contents, Tank 4E01, Assume spill at BLEU complex storage tank	UNT (7.25, 7.35, 7.45, 7.51)	Low
4	Loss of contents, Tank 4E01, Assume outside spill	UNT (7.37, 7.38, 7.41, 7.42, 7.43, 7.44, 7.47)	Low
5	Loss of contents, Tank 4C01, Assume outside spill	UNT (7.8, 7.64, 7.65, 7.66, 7.67)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
6	Loss of ventilation or containment for vapor from Tank 4E01. Assume vapor release in LEU area	UNT (7.23, 7.24, 7.53, 7.54, 7.56)	Low
***	Potential Fire	UNT (7.43)	Deemed Highly Unlikely in Fire Protection ACE
		Process Scrubber	
1	Potential overflow or spill of scrubber to floor	PS (45.5, 45.7, 45.11, 45.13, 45.17, 45.33, 45.60, 45.64, 45.66, 45.79, 45.83, 45.87, 45.89, 45.91, 45.95, 45.96, 45.101, 45.106, 45.112, 45.136, 45.138)	Low
2	Potential spill of ventilation condensation	PS (45.19, 45.46)	Low
3	Potential for loss of ventilation with a potential exposure at the source points	PS (45.31, 45.32, 45.34, 45.38, 45.40, 45.41, 45.52, 45.111)	Evaluated in Source Point Area Evaluation (High for NOx)
4	Sodium Hydroxide Day Tank spill (Assume pump rate of 50 gallons per minute for 5 minutes)	PS (45.120, 45.132, 45.134)	Intermediate
5	Spill of Sodium Hydroxide during maintenance	PS (45.4)	Low
6	Spill of Scrubber solution during maintenance	PS (45.21, 45.25, 45.78, 45.81, 45.107)	Low
7	Spill of Blowdown solution at Waste Water Treatment Facility	PS (45.88)	Low
8	Spill of 67% Nitric Acid, 5700 gallon Bulk supply	PS (45.118)	High
9	Blowdown Tank spill	PS (45.70, 45.75, 45.80, 45.84, 45.92, 45.126, 45.142)	Low
10	Vapor Release into work area	PS (45.140, 45.141, 45.143, 45.144	No significant exposure expected
	Release of NOX to Environment	PS (45.2, 45.3, 45.7, 45.10, 45.11, 45.12, 45.13, 45.14, 45.22, 45.24, 45.26, 45.28, 45.29, 45.67, 45.109, 45.112, 45.120, 45.127, 45.131, 45.136, 45.138	Addressed in Environmental ACE

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		Ventilation Knockout Columns	
1	Loss of Contents; 2I08; 3E01; 1L01; assuming contents or U and solvent	VKC (25.3; 25.5; 25.6)	Low Consequences addressed in area evaluations
	Potential Fire	VKC (25.3; 25.5; 25.6)	Deemed Highly Unlikely in Fire Protection ACB
		Process Exhaust Ventilation	
1	Potential for loss of ventilation at the enclosure source points resulting in potential employee exposure	PV (44.2; 44.3; 44.5; 44.7; 44.9; 44.11; 44.17; 44.18; 44.20; 44.23; 44.24)	Evaluated in Source Point Area Evaluation (High for NOx)
2	Potential spill of ventilation condensation	PV (44.14; 44.21)	Low
3	Potential Explosion due to buildup of hydrogen at source points; Potential fire	PV (44.3; 44.21)	Evaluated in U aluminum Scenario 8 (High)
	Potential Release of Contamination to Scrubber/Main Stack	PV (44.1; 44.22)	No Chemical Consequences Identified
		Utilities	
1	Cooling Water line breaks; Cooling water spill into work area	UTD (40.1)	No significant exposure expected
2	No Cooling Water to Downstream Process Areas	UTD (40.2; 40.4; 40.7)	Evaluated in Individual Process Areas
3	Nitrogen Supply line breaks; Nitrogen release into work area	UTD (40.9)	Low
4	No Nitrogen to Downstream Process Areas	UTD (40.12; 40.16)	Evaluated in Individual Process Areas
5	Nitric Acid line breaks; Nitric Acid spill into work area	UTD (40.17)	High

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
6	No Nitric Acid to Downstream Process Areas	UTD (40.20, 40.24)	Evaluated in Individual Process Areas
7	Plant Air line breaks; Plant Air release into work area	UTD (40.25)	n/a
8	No Plant Air to Downstream Process Areas	UTD (40.26, 40.28, 40.32)	Evaluated in Individual Process Areas
9	Hydrogen Peroxide line breaks; Hydrogen Peroxide spill into work area	UTD (40.41)	Low
10	No Hydrogen Peroxide to Downstream Process Areas	UTD (40.44, 40.48)	Evaluated in Individual Process Areas
11	NOx release to environment	UTD (40.49, 40.50, 40.52, 40.56)	Addressed in Environmental ACE
		Caustic Discharge System (Liquid Waste Discard)	
1	Caustic Discharge Tank spill through tank failure; Assume 1 centimeter spill depth in Dike Discard Area	CD (27.1)	Intermediate
1a	Caustic Discharge Tank spill through valve or pump failure; Assume pump rate of 12 gallons per minute for 1 hour	CD (27.27, 27.31, 27.39, 27.54)	Low
2	Caustic Discharge Tank Overpressurization; Assume 1 centimeter spill depth in Dike Discard Area	CD (27.26)	Intermediate
3	Caustic Discard Columns, Bank A or B, valve failure; Assume 760 liter spill in HEU area	CD (27.2, 27.4, 27.12)	Low
4	Caustic Discard Columns, Bank A or B, overflow Discard Tank; Assume 760 spill in Dike Discard area	CD (27.21)	Intermediate

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
5	Loss of Residual Solution in Line during maintenance	CD (27.32)	Low
6	Assume spill at Waste Water Treatement Facility from Caustic Discharge Tank	CD (27.37)	Low
7	Overflow Discard Tank with Water	CD (27.24, 27.42)	No significant exposure expected
8	Incompatible Materials added to Discard Tank	CD (27.43)	No significant exposure expected
9	Vapor release due to line failure	CD (27.48, 27.49)	No significant exposure expected
10	Caustic Discharge Tank Tank Failure	CD (27.1)	Intermediate
11	Pump Breech	CD (27.54)	Intermediate
	Nitric Discharge System (Liquid Waste Discard)		
1	Loss of Contents, Nitric Discharge Tank, through Tank Failure, Valve Failure, Overflow (bounding)	ND (26.1, 26.2, 26.4, 26.12, 26.21, 26.23, 26.24, 26.26, 26.27, 26.31, 26.32, 26.37, 26.39, 26.41, 26.42, 26.43, 26.46, 26.50, 26.51)	Low
	Chemical Toxicity – Soluble Uranium		
1	Free-fall Spill HE UN solution SX Area dilution volume (SXFC 9.3, 9.5, 9.9, 9.11, 9.25, 9.27)	UMM (8.5, 8.10, 8.12, 8.19), SXFC (9.3, 9.5, 9.9, 9.11, 9.25, 9.27), SXPS (22.59, 22.61, 22.67, 22.70)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
2	Spill (Free-fall and Puncture) HE UN solution SX Area dilution volume (UMM 8.17)	1UMD (1.154), 2UMD (2.154), 3DT (3.1, 3.2, 3.3, 3.10, 3.11, 3.13, 3.14, 3.18, 3.19, 3.20, 3.21, 3.23, 3.24, 3.25, 3.33, 3.36, 3.37, 3.49, 3.50), 7DT (4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.14, 4.16, 4.17, 4.19, 4.20, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33, 4.35, 4.36, 4.37, 4.41, 4.45, 4.47), UDB (5.1, 5.3, 5.5, 5.8, 5.13, 5.14, 5.16, 5.18, 5.20, 5.22, 5.24, 5.26, 5.28, 5.30, 5.32, 5.34, 5.44, 5.46), UMM (8.1, 8.3, 8.15, 8.16, 8.17, 8.20, 8.22, 8.23, 8.26), SXFC (9.13, 9.14, 9.21, 9.22, 9.28, 9.30, 9.31, 9.34, 9.39, 9.44, 9.45, 9.46, 9.47, 9.50, 9.52, 9.53, 9.60, 9.62, 9.64, 9.65), 1PX (10.90, 10.92, 10.98, 10.100, 10.106, 10.108), 1PE 12.59, 2PSX (13.58, 13.60, 13.66, 13.68), SXSF (16.1, 16.9, 16.15, 16.16, 16.19, 16.31, 16.37, 16.39, 16.40, 16.44, 16.45, 16.55, 16.57), SXPS (22.3, 22.5, 22.26, 22.28, 22.30, 22.32, 22.36, 22.38, 22.40, 22.41, 22.43, 22.45, 22.46, 22.47, 22.48, 22.49, 22.50, 22.51, 22.52, 22.53, 22.55, 22.63, 22.72, 22.74), 1UALS 33.95, 2UALS 34.88, UALAC (37.3, 37.5, 37.6, 37.9, 37.10, 37.11, 37.13, 37.16, 37.17, 37.18, 37.28, 37.29, 37.33, 37.38, 37.42, 37.46)	Low
3	Catastrophic Rupture/Resuspension HB UN Solution Main Bldg Area dilution volume (UMM 8.32)	3DT 3.52, 7DT 4.48, UDB 5.146, UMM 8.32, UALAC 37.39	Low
4	Employee exposure simmering HE UN solution Main Bldg Area dilution volume (1UMD 1.48, 1.50, 1.111, 1.113, 1.114, 1.116, 1.120, 1.134, 1.135)	1UMD (1.48, 1.50, 1.111, 1.113, 1.114, 1.116, 1.120, 1.134, 1.135), 2UMD (2.48, 2.50, 2.111, 2.113, 2.114, 2.116, 2.120, 2.134, 2.135), 1UALS (33.1, 33.3, 33.5, 33.7, 33.12, 33.13, 33.104), 1UALS (34.1, 34.3, 34.5, 34.7, 34.12, 34.13, 34.102)	Low
5	Employee exposure 2000 gallons Nitric Waste Solution Discard Dike Room dilution volume (ND 26.50, 26.51)	ND (26.50, 26.51)	Low
6	Leak in FRNCOV-3A01 U-Metal Main Bldg Area dilution volume (1UMD 1.71)	1UMD (1.62, 1.63, 1.64, 1.65, *1.67, 1.68, 1.71, *1.73, 1.74, 1.137, 1.149, 1.164), 2UMD (2.62, 2.63, 2.64, 2.65, *2.67, 2.68, 2.71, *2.73, 2.74, 2.137, 2.149, 2.164), UMS (39.9, 39.13)	NA
7	Free-fall Spill U-Metal Main Bldg Area dilution volume (UMS 39.3)	1UMD 1.171, UMS (39.3, 39.5, 39.8, 39.11)	NA

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
8	Spill from ENCLOS-3A18 drain 40L simmering HEU Soln (Class Y) Main Bldg Area dilution volume 1UMD (1:19, 1:44, 1:47, 1:53, 1:56, 1:59, 1:79, 1:80, 1:82, 1:86, 1:87, 1:106, 1:107, 1:109, 1:124, 1:128, 1:136, 1:147, 1:148, 1:150, 1:152, 1:156, 1:158, 1:161)	1UMD (1:1, 1:19, 1:44, 1:47, 1:53, 1:56, 1:59, *1:79, 1:80, *1:82, 1:86, 1:87, 1:106, 1:107, *1:109, 1:124, 1:128, 1:136, 1:147, 1:148, 1:150, 1:152, *1:156, 1:158, 1:161, 1:162), 2UMD (2:1, 2:19, 2:44, 2:47, 2:53, 2:56, 2:59, *2:79, 2:80, *2:82, 2:86, 2:87, 2:106, 2:107, *2:109, 2:124, 2:128, 2:136, 2:147, 2:148, 2:150, 2:152, *2:156, 2:158, 2:161, 2:162), 1UALS (33:10, 33:14, 33:16, 33:19, 33:62, 33:66, 33:69, 33:71, 33:74, 33:75, 33:77, 33:89, 33:90), 2UALS (34:10, 34:14, 34:16, 34:19, 34:55, 34:59, 34:62, 34:64, 34:67, 34:68, 34:70, 34:82, 34:83)	NA
9	Employee Exposure POG line breach while filling Natural UN tanker (UNT 7:54)	UNT (7:54)	Intermediate Note: Source material as per S86001
10	Employee exposure ENCLOS-3EO3 POG line plugs U-Metal Main Bldg Area dilution volume (UMS 39:2, 39:12)	UMS (39:2, 39:12)	NA
11	Spill (puncture vs. free-fall) LB UN solution LEU Area dilution volume (UNT 7:13)	UDB (5:78, 5:83, 5:84, 5:91, 5:93, 5:94, 5:97, 5:100, 5:101, 5:103), UNT (7:5, 7:8, 7:12, 7:13, 7:17, 7:19, 7:20, 7:38, 7:45, 7:50)	Low
12	Free-fall Spill LE UN simmering Natural UN Natural UN LEU Area dilution volume (UDB 5:116)	UDB (5:55, 5:80, 5:88, 5:116, 5:120, 5:129), UND (6:199, 6:243)	Low
13	Spill (Free-fall and puncture) simmering NUN LEU Area dilution volume (UND 6:62)	UDB (5:52, 5:54, 5:57, 5:122, 5:126, 5:128, 5:132, 5:144, 5:145), UND (6:39, 6:41, 6:46, 6:62, 6:66, 6:69, 6:71, 6:72, 6:80, 6:81, 6:93, 6:95, 6:100, 6:101, 6:102, 6:104, 6:108, 6:176, 6:177, 6:179, 6:184, 6:186, 6:188, 6:190, 6:193, 6:196, 6:211, 6:212, 6:221, 6:227, 6:228, 6:229, 6:235, 6:236, 6:237, 6:238, 6:241, 6:242), UNT (7:31, 7:37, 7:41, 7:42, 7:45, 7:46, 7:47, 7:61)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
14	Spill (Free-fall and Puncture) 2000 gallons Nitric Waste Solution Discard Dike Room dilution volume Plus 1820L Condensate Solution SX Area dilution volume (ND 26.24)	ECA (20.2, 20.4, 20.5, 20.7, 20.8, 20.10, 20.11, 20.21); ECB (21.1, 21.3, 21.4, 21.6, 21.7, 21.17); ND (26.1, 26.2, 26.4, 26.12, 26.19, 26.24, 26.27, 26.29, 26.31, 26.32, 26.39, 26.41, 26.42, 26.43, 26.46, 26.48)	Low
15	Rupture/Resuspension simmering NUN LEU Area dilution volume (UND 6.225)	UND (6.59, 6.60, 6.225)	Intermediate Note: Source material as per S86001
15A	Rupture/Resuspension simmering NUN LEU Area dilution volume (UDB 5.140)	UDB 5.140, UND 6.84	Low
16	Employee exposure LE UN NUN LEU Area dilution volume (UDB 5.142)	UDB (5.139, 5.141, 5.142, 5.143)	Low
17	Drum Lift Hydraulic System Fails LEU Area dilution volume (UND 6.20, 6.21)	UND (*6.1, *6.2, *6.3, *6.10, *6.11, *6.12, *6.18, *6.20, *6.21, 6.26, 6.32)	Low
18	Spill (Free-fall and puncture) Natural UN Outside dilution volume (UNT 7.39)	UNT (7.39, 7.40, 7.44)	Low
19	Employee exposure Caustic Waste Solution Main Bldg Area dilution volume (1UALC 35.42)	1UALC 35.42, 2UALC 36.42	NA
20	Free fall spill from 4.5 meters 1312 lbs natural UO_3 powder LEU Area dilution volume (UND *6.22, *6.23, *6.35)	UND (*6.22, *6.23, *6.35)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
21	Employee exposure HE UN Solution Main Bldg Area dilution volume (UMM 8.33)	3DT (3.43, 3.46, 3.47, 3.53); 7DT 4.49; UDB 5.147; UMM 8.33; UALAC (37.36, 37.37, 37.40); PS 45.100	Low
22	Employee exposure simmering NUN LEU Area dilution volume (UND 6.68, 6.158, 6.165, 6.172, 6.173, 6.187, 6.224, 6.226)	UND (6.68, 6.158, 6.165, 6.172, 6.173, 6.187, 6.224, 6.226, 6.233, 6.240, 6.256)	Low
23	Excessive Exothermic Rx Natural UN LEU Area dilution volume (UND *6.27, 6.30, *6.32, 6.63, 6.64)	UND (*6.27, 6.30, *6.32, 6.63, 6.64)	Low
24	Resuspension (POG plug) Natural UO_2 powder LEU Area dilution volume (UND 6.25)	UND (6.25, 6.246)	Low
25	Employee exposure LE UN Solution LEU Area Dilution Volume (UNT 7.23, 7.24, 7.56)	UNT (7.23, 7.24, 7.56)	Low
26	Catastrophic Rupture/Resuspension LE UN LEU Area dilution volume (UNT 7.22)	UDB 5.138; UNT 7.22	Intermediate
27	Spill (Free fall and Puncture) LE UN Solution at BLEU Complex (UNT 7.25, 7.35, 7.51)	UNT (7.25, 7.35, 7.51)	Low
28	Rupture/Resuspension NUN Outside dilution volume (UNT 7.3, 7.53)	UNT (7.3, 7.53, 7.65)	Intermediate Note: Source material as per S8600T

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
29	Employee Exposure 750 gallons Scrubber Solution Main Discard Dike Area dilution volume (PS 45.57)	PS 45.57	Low
30	Fire of Natural UN Tanker (UNT 7.43)	UNT 7.43	Low
31	Free fall spill 7 cans U-Al from 8ft Main Bldg Area dilution volume (HSSA 28.7)	HSSA (28.7, 28.13, 28.14)	NA
32	Free fall spill 6 cans U-Al from 18ft Main Bldg Area dilution volume (HSSA 28.15)	HSSA 28.15	NA
33	Spill (Free-fall and Puncture) 1250 gallons Scrubber Solution Discard Dike Area dilution volume plus Loss of Ventilation Resulting in Exposure at Source Points (PS 45.41)	PV (44.2, 44.7, 44.9, 44.11, 44.14, 44.20); PS (45.5, 45.7, 45.11, 45.13, 45.17, 45.19, 45.21, 45.25, 45.31, 45.33, 45.34, 45.37, 45.38, 45.40, 45.41, 45.46, 45.48, 45.52, 45.54, 45.55, 45.60, 45.64, 45.66, 45.70, 45.72, 45.73, 45.75, 45.78, 45.79, 45.80, 45.83, 45.84, 45.87, 45.89, 45.91, 45.92, 45.95, 45.96, 45.101, 45.106, 45.107)	Low
34	Red Oil Incident	1PX (10.55, 10.57, 10.63); 2PSX (13.35, 13.37, 13.41, 13.71)	High Note: Assumed based on inherent severity of Red Oil Incident
35		INTENTIONALLY LEFT OPEN FOR FUTURE USE	
36	Catastrophic Rupture/Resuspension HE UN Solution SX Area dilution volume (SXPS 22.34)	SXFC 9.37; SXPS 22.34	Low
37	Employee Exposure HE UN SX Area dilution volume (SXPS 22.35)	SXFC 9.38; 1PX 10.129; 2PSX 13.86; SXSF (16.14, 16.27, 16.28, 16.29); SXPS 22.35	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
38	Employee Exposure 1000 gallons Caustic Waste Solution Discard Dike Room dilution volume (CD 27.48, 27.49)	CD (27.48, 27.49), PS 45, 105	NA
39	Spill (Free-fall and Puncture) Raffinate/Condensate/HEU Solution plus Fire of Solvent SX Area dilution volume (1PX 10.2)	1PX (10.2, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.56, 10.58, 10.59, 10.60, 10.61, 10.62, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.75, 10.77, 10.78, 10.80, 10.81, 10.83, 10.85, 10.86, 10.88, 10.89, 10.91, 10.94, 10.95, 10.96, 10.97, 10.99, 10.103, 10.104, 10.105, 10.107, 10.109, 10.110, 10.112, 10.116, 10.119, 10.122, 10.124, 10.126), 1PSW (11.2, 11.6, 11.10, 11.11, 11.12, 11.13, 11.14, 11.22, 11.24, 11.25, 11.26, 11.27, 11.28, 11.30, 11.40, 11.41, 11.48, 11.49, 11.50, 11.51, 11.52, 11.53, 11.54, 11.55, 11.56, 11.58, 11.60, 11.62, 11.65, 11.67, 11.68, 11.69, 11.70, 11.73, 11.74, 11.77, 11.78, 11.80, 11.82, 11.84, 11.85, 11.90, 11.91, 11.92, 11.94, 11.99, 11.101, 11.102, 11.103, 11.106, 11.112, 11.114), 2PSX (13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.36, 13.38, 13.39, 13.40, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.51, 13.53, 13.54, 13.56, 13.57, 13.59, 13.62, 13.63, 13.64, 13.65, 13.67, 13.69, 13.70, 13.72, 13.75, 13.77, 13.80, 13.82, 13.84), 2PSW (14.2, 14.6, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.25, 14.26, 14.27, 14.28, 14.30, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.58, 14.60, 14.62, 14.65, 14.67, 14.68, 14.69, 14.70, 14.73, 14.74, 14.77, 14.78, 14.80, 14.82, 14.84, 14.85, 14.90, 14.91, 14.92, 14.94, 14.99, 14.101, 14.102, 14.103, 14.106, 14.108, 14.110), 1PRS (17.3, 17.5, 17.9, 17.11, 17.19, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.33, 17.45, 17.47, 17.65), 2PRS (18.2, 18.9, 18.11, 18.12, 18.14, 18.16, 18.18, 18.22, 18.29, 18.33), SXSC (19.5, 19.9, 19.11, 19.12, 19.14, 19.20), ECA 20.17, ECB 21.13, 1SXCM (23.34, 23.55), 2SXCM (24.16, 24.18, 24.20, 24.22), VKC (25.3, 25.5, 25.6), UTD (40.26, 40.28, 40.32)	Low
40	Spill (Free-fall and Puncture) 1000 gallons Caustic Waste Solution Discard Dike Room dilution volume Plus 1520L Caustic Waste Solution Main Bldg Area dilution volume (CD 27.24, 27.42)	CD (27.1, 27.2, 27.4, 27.12, 27.16, 27.17, 27.18, 27.19, 27.24, 27.27, 27.29, 27.31, 27.32, 27.39, 27.41, 27.42, 27.43, 27.46), 1UALC (35.3, 35.8, 35.9, 35.12, 35.13, 35.14, 35.16, 35.19, 35.20, 35.21, 35.34, 35.37, 35.44, 35.48), 2UALC (36.3, 36.8, 36.9, 36.12, 36.13, 36.14, 36.16, 36.19, 36.20, 36.21, 36.34, 36.37, 36.44, 36.48)	NA

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
41	Catastrophic Rupture/Resuspension 760L Caustic Waste Solution Main Bldg Area dilution volume (1UALC 35.41)	1UALC 35.41; 2UALC 36.41	NA
42	Spill (Free-fall and Puncture) simmering HE UN Solution 1820L Condensate Solution SX Area dilution volume (1PE 12.95)	1PE (12.24, 12.26, 12.30, 12.32, 12.34, 12.45, 12.52, 12.55, 12.56, 12.60, 12.61, 12.62, 12.63, 12.64, 12.65, 12.66, 12.67, 12.68, 12.69, 12.70, 12.72, 12.73, 12.74, 12.75, 12.79, 12.80, 12.81, 12.82, 12.83, 12.95, 12.100, 12.102, 12.103, 12.106, 12.107, 12.108, 12.110, 12.113, 12.114, 12.115, 12.116, 12.117, 12.118, 12.120, 12.121, 12.122, 12.130, 12.167, 12.179); 2PE (15.24, 15.26, 15.30, 15.32, 15.34, 15.47, 15.50, 15.51, 15.54, 15.55, 15.56, 15.57, 15.58, 15.59, 15.60, 15.61, 15.62, 15.63, 15.64, 15.66, 15.67, 15.68, 15.69, 15.73, 15.74, 15.75, 15.76, 15.77, 15.89, 15.92, 15.94, 15.95, 15.96, 15.98, 15.99, 15.100, 15.104, 15.141, 15.153)	Low
43	Catastrophic Rupture/Resuspension 650L 2nd Pass Raffinate Solution SX Area dilution volume (SXSC 19.22)	1PRS 17.61; 2PRS 18.26; SXSC 19.22	Low
44	Employee exposure 650L 2nd Pass Raffinate Solution SX Area dilution volume (SXSC 19.23)	1PSW 11.116; 2PSW 14.116; 1PRS 17.62; 2PRS 18.27; SXSC 19.23	Low
45	Catastrophic Rupture/Resuspension 910L Condensate Solution SX Area dilution volume (ECA 20.31)	ECA 20.31; ECB 21.27	Low
46	Spill (Free-fall and Puncture) 650L 2nd Pass Raffinate Solution SX Area dilution volume (SXSC 19.9)	1PX (10.74, 10.76, 10.82, 10.84); 1PSW (11.1, 11.3, 11.8, 11.57, 11.59, 11.61, 11.63, 11.71, 11.75, 11.79, 11.83, 11.93, 11.95, 11.107); 1PE 12.128; 2PSX (13.50, 13.52); 2PSW (14.1, 14.8, 14.57, 14.59, 14.61, 14.63, 14.71, 14.75, 14.79, 14.83, 14.93, 14.95, 14.111); 2PE 15.102; SXSF (16.41, 16.52); 1PRS (17.14, 17.15, 17.32, 17.34, 17.51, 17.37); 2PRS (18.17, 18.19, 18.30, 18.34, 18.35); SXSC 19.15	Low
47	Employee exposure boiling HE UN Solution simmering HE UN Solution room temp HE UN Solution SX Area dilution volume (1PE 12.132)	1PE (12.28, 12.85, 12.89, 12.91, 12.99, 12.132); 2PE (15.28, 15.79, 15.83, 15.85, 15.91, 15.106)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
48	Employee exposure 910 liters Condensate Solution SX Area dilution volume (ECA 20.32)	ECA 20.32; ECB 21.28	Low
49	Loss of Cooling Water to Plant Processes resulting in Exposure at Source Points (UTD 40.4)	UTD (40.1; 40.2; 40.4)	Low
50	Employee exposure 1000 gal Cooling Water Pit 46.3 ft³ dilution volume (1UMD 1.54)	1UMD 1.54; 2UMD 2.54; UND (6.110; 6.189); 1PE 12.94; 2PE 15.88; 1UALD 29.46; 2UALD 30.46; 3UALD 31.46; 4UALD 32.46; 1UALS 33.11; 2UALS 34.11	Low
51	Loss of Nitrogen to Plant Processes resulting in UAl Hydrogen Explosion (UTD 40.9; 40.12; 40.16)	UTD (40.9; 40.12; 40.16)	Low
52	Spill (Free-fall and puncture) Simmering U-Al Dissolver Soln plus Caustic Waste Soln bound by Evaluation # 40 Main Bldg Area dilution volume (1UALS 33.21)	1UALD (*29.16; 29.22; 29.27; *29.31; *29.33; *29.35; 29.60; 29.77); 2UALD (*30.16; 30.22; 30.27; *30.31; *30.33; *30.35; 30.60; 30.77); 3UALD (*31.16; 31.22; 31.27; *31.31; *31.33; *31.35; 31.60; 31.77); 4UALD (*32.16; 32.22; 32.27; *32.31; *32.33; *32.35; 32.60; 32.77); 1UALS (33.21; *33.24; 33.27; 33.28; 33.29; 33.30; 33.33; 33.34; 33.35; 33.36; 33.37; 33.39; 33.41; 33.42; 33.43; 33.45; 33.46; 33.47; 33.48; 33.49; 33.50; 33.51; 33.107; 33.108; 33.109; 33.111); 2UALS (34.21; *34.24; 34.27; 34.28; 34.29; 34.30; 34.33; 34.34; 34.35; 34.36; 34.37; 34.39; 34.41; 34.42; 34.43; 34.45; 34.46; 34.47; 34.48; 34.49; 34.50; 34.51; 34.105; 34.106; 34.107; 34.109); 1UALC (35.7; 35.25; 35.36); 2UALC (36.7; 36.25; 36.36); CMST (*38.16; *38.17; *38.18; *38.19; *38.20; *38.31; *38.32; *38.33; *38.34; *38.36)	NA
53	Explosion from Vented H₂ into POG U-Al U-Al Dissolver Solution Main Bldg Area dilution volume (1UALD 29.45; 29.48; 29.49; 29.57; 29.59; 29.66; 29.70)	1UALD (29.23; 29.25; 29.26; 29.30; 29.45; 29.48; 29.49; 29.57; 29.59; 29.66; 29.70; 29.78; 29.80); 2UALD (30.23; 30.25; 30.26; 30.30; 30.45; 30.48; 30.49; 30.57; 30.59; 30.66; 30.70; 30.78; 30.80); 3UALD (31.23; 31.25; 31.26; 31.30; 31.45; 31.48; 31.49; 31.57; 31.59; 31.66; 31.70; 31.78; 31.80); 4UALD (32.23; 32.25; 32.26; 32.30; 32.45; 32.48; 32.49; 32.57; 32.59; 32.66; 32.70; 32.78; 32.80)	Low
54	Employee exposure ENCLOS-3A18 POG line plug U-Metal Main Bldg Area dilution volume (1UMD 1.76; 1.138)	1UMD (1.76; 1.138); 2UMD (2.76; 2.138)	NA

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
55	Employee exposure U-Al simmering U-Al dissolver soln Main Bldg Area dilution volume (1UALD 29.68)	1UALD (*29.63, *29.64, 29.68), 2UALD (*30.63, *30.64, *30.68), 3UALD (*31.63, *31.64, *31.68), 4UALD (*32.63, *32.64, *32.68), PV (44.3, 44.5, 44.17, 44.18, 44.21, 44.23)	[1]NA

[1]NA: Chemical toxicity neglected. As per DOE-STD-1136-2000 page 2-29, for Class Y materials radiological hazards are limiting for enrichments > 0.82%, therefore scenario not evaluated for chemical toxicity.

*Explosion/Fire: Likelihood deemed not credible by Fire Protection Safety Evaluation, therefore not included as part of scenario: 1UMD (1.67, 1.73, 1.79, 1.82, 1.109, 1.156), 2UMD (2.67, 2.73, 2.79, 2.82, 2.109, 2.156), UND (6.1, 6.2, 6.3, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11, 6.12, 6.18, 6.20, 6.21, 6.22, 6.23, 6.35), UND (6.27,6.29,6.32), 1UALD (29.16, 29.31, 29.33, 29.35, 29.63, 29.64, 29.68), 2UALD (30.16, 30.31, 30.33, 30.35, 30.63, 30.64, 30.68), 3UALD (31.16, 31.31, 31.33, 31.35, 31.63, 31.64, 31.68), 4UALD (32.16, 32.31, 32.33, 32.35, 32.63, 32.64, 32.68), 1UALS 33.24, 1UALS 34.24, CMST (38.16, 38.17, 38.18, 38.19, 38.20, 38.31, 38.32, 38.33, 38.34, 38.36)

Not Classified: Scenario involves work safety issue only, not an accident resulting from a process upset.

BPF Consequence Evaluation (occupational) not performed:

- Inadvertent transfer to Waste Water Treatment Facility. Bound by Waste Water Treatment ISA (ND 26.37, CD 27.37)
- Environmental release of contamination. No safety concern from an occupational standpoint. [UTD (40.49, 40.50, 40.52, 40.56), PV (44.1, 44.22), PS (45.10, 45.14, 45.16, 45.22, 45.24, 45.26, 45.28, 45.32, 45.59, 45.61, 45.63, 45.67)]
- Potential loss of H_2O_2 to plant processes. No safety concern from an occupational uranium chemical toxicity standpoint. [UTD (40.41, 40.44, 40.48)]

4.2.3 Radiological Safety Consequence Analysis (Worker)

The accident scenarios for evaluation are provided on tables developed by an ISA team during a Process Hazard Analysis. Multiple types of consequences can result from the same event (item number) on the table, therefore the analysis is conducted for the most severe consequence for each item number. Upon completion of the analysis, each credible accident scenario is assigned an unmitigated, uncontrolled consequence severity category based on 10 CFR 70.61 as shown below:

- High Consequence – An accident resulting in an acute worker TEDE of 100 rem or greater
- Intermediate Consequence - An accident resulting in an acute worker TEDE of greater than or equal to 25 rem but less than 100 rem
- Low Consequence – Consequences that are not high or intermediate

Inhalation Methodology

The methodology utilized for consequence evaluation is consistent with guidance provided in NUREG/CR-6410, "Nuclear Fuel Cycle Facility Accident Analysis Handbook", and supplemented as necessary with guidance provided in DOE-HDBK-3010-94, "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities". The following sections provide an overview of the methodology used to determine exposure levels for the inhalation pathway.

Step 1 – Determine Airborne Source Term

The first step of the methodology is to determine the airborne source term (ST_{Air}). The amount of material available for dispersion. This calculation was accomplished using the Five-Factor Formula defined in Section 3.2.5.2 of NUREG/CR-6410.

$$ST_{Air} = MAR * DR * ARF * RF * LPF$$

The Material at Risk (MAR) is the amount of hazardous material available to be acted on by a given physical stress.

The Damage Ratio (DR) is the fraction of MAR actually impacted by a given physical stress from a specific event. The DR for accident scenarios was assumed to be 1.

The Leakpath Factor (LPF) is the fraction of airborne material of concern that leaves the confinement/containment barrier after considerable depletion mechanisms. For conservatism, the LPF is assumed to be negligible for determining exposures to the worker.

The Airborne Release Fraction (ARF) is the fraction of impacted material that can be suspended to become available for airborne transport following a specific set of induced physical stresses. The ARF is a joint function of the original physical and chemical state of material and the type of stress. The ARF will be based on guidance in NUREG/CR-6410, "Nuclear Fuel Cycle Facility Accident Analysis Handbook", and supplemented as necessary with guidance provided in DOE-HDBK-3010-94, "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities".

The Respirable Fraction (RF) is the fraction of the material of concern initially suspended in the air and present as particles that can be inhaled into the human respiratory system. The RF will be based on guidance in NUREG/CR-6410, "Nuclear Fuel Cycle Facility Accident Analysis Handbook", and supplemented as necessary with guidance provided in DOE-HDBK-3010-94, "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities".

Step 2 – Determine Resultant Airborne Concentration

The second step of the methodology is to determine the resultant airborne concentration utilizing a dilution factor. The quantity of released material is assumed dispersed into a volume equal to the volume of building or estimated space in which the accident occurs. General facility baseline data used, including building dimensions and volumes per Table 2-2, U-metal sampling baseline data per 300 Complex Air Changes (BPF-FMF, dated February 27, 2003), and UNB overfill scenario per BLEU Uranyl Nitrate Building (UNB) Fire Hazard Analysis Rev. 5 (September 5, 2002) Section 3.1.

The dilution volume for outdoor liquid releases is estimated as follows:

- The total potential area of the liquid spill is estimated using the formula used by the Federal Emergency Management Agency's (FEMA) document titled *Handbook of Chemical Hazard Analysis Procedures*:

  $\log(A) = 0.492 \log(M) + 1.617$ where
  A = Pool size in square feet
  M = Pounds of chemical spilled

- Conservatively assumed worker exposed to 6-foot height to calculate dilution volume of the spill.

The dilution volume for workers exposed to the source term resuspended into the void space of the tank trailer is estimated as follows:

- Void space assumed to be total tank trailer volume minus tank trailer liquid volume.

Step 3 – Determine Dose Due to Inhalation

The third step of the methodology is to determine the dose to the worker due to the inhalation of the dispersed material. The worker dose is estimated by determining the Derived Air Concentration - hour (DAC-hour) for the material assuming the worker is exposed for the given duration and applying a dose equivalent of 5 rem per 2000 DAC-hours.

Step 4 – Determine Soluble Uranium Intake

The fourth step of the inhalation calculation methodology requires the determination of the soluble uranium intake for the worker.

The uranium intake for the worker is calculated as part of the Radiological Consequences; however, the results of the calculations and the associated controls are discussed in the Chemical Consequences, Section 4.2.2.

Worker External Exposure Methodology

Although the primary pathway for personnel exposure is an internal exposure pathway, exposure to direct radiation contributes to the TEDE. The types of radioactive material are considered low external exposure hazards. However, for the purposes of accident analysis, MicroShield Version 5 was used to estimate exposure from gamma radiation using the proposed source term. The resultant external dose is considered an insignificant contribution to an intermediate or high consequence determination.

The external dose calculations were performed using MicroShield version 5.03. Each nuclide of interest was entered as a source term in the program and for simplicity, the calculations were performed for an initial activity of 1 Ci for each nuclide. The form of the radioactive material and the type of container in which the material is present will also impact the exposure potential. Therefore, for conservatism, each nuclide of interest was assumed to be a point source. It is conservatively assumed that a worker would remain an average of 3 feet from the source while in the area. In the case of the photons in the energy range of interest for these nuclides, the dose equivalent in soft tissue in units of mrem/hr is approximately equal to the exposure rate in mR/hr for air. Therefore, the results obtained from MicroShield were used with a 1:1 conversion from mR/hr to mrem/hr.

Bounding radiological consequence evaluations (worker) were developed and the PHA radiological scenarios were grouped under one of these evaluations. The results of bounding evaluations and the scenario grouping are provided in Table 4-2.

4.2.3.1 Uranium Metal Dissolution Process (Radiological Consequences)

Radiological hazards present in the U-Metal Dissolution Process include Class Y HEU solid/slurry and Class D HEUN solution. The radiological hazard present in the U-Metal Sampling Process is Class Y HEU solid. The radionuclide concentrations for the Process Materials are as specified in the *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (21T-02-0300). The Materials at Risk (MAR) for the accident scenarios will be the quantities of material present as summarized in the table below.

Uranium Metal Dissolution Process Materials at Risk

Source	Material Description	Quantity	Maximum gU/L	Solubility Class	Physical Form
P&ID 306-F0701-D (BPF U-Metal Sampling):					
ENCLOS-3E03	HEU		[a]NA	Y	Solid
P&ID 333-F0400-D (U-Metal Dissolution, Sheet 1):					
ENCLOS-3A18	HEU		[a]NA	Y	Solid
FRNCOV-3A01	HEU		[a]NA	Y	Solid
DISOLV-3A05	HEU/HEUN		[b]400	[c]Y/D	Slurry/Liquid
DISOLV-3A22	HEU/HEUN		[b]400	[c]Y/D	Slurry/Liquid
P&ID 333-F0401-D (U-Metal Dissolution, Sheet 2):					
ENCLOS-3B18	HEU		[a]NA	Y	Solid
FRNCOV-3B01	HEU		[a]NA	Y	Solid
DISOLV-3B05	HEU/HEUN		[b]400	[c]Y/D	Slurry/Liquid
DISOLV-3B22	HEU/HEUN		[b]400	[c]Y/D	Slurry/Liquid
P&ID 333-F0402-D (U-Metal 3 Day Test Columns, Sheet 3):					
COLUMN3C01-03	HEUN		[b]400	D	Liquid
P&ID 333-F0403-D (U-Metal 7 Day Test Columns, Sheet 4):					
COLUMN3D01-06	HEUN		[b]400	D	Liquid

[a] Conservatively assumed maximum of 12 kg U per can as identified by NCSE.
[b] Assumed as concentrated heavy metal solution ~30% above projected nominal mass balance value stated in NFS Engineering Project Definition.
[c] Assumed as Class Y prior to metering in of HNO_3

4.2.3.2 UAl Dissolution Process (Radiological Consequences)

Radiological hazards present in the U-Al_x Dissolution Process include Class Y HEU solid/slurry/solution, Class D HEUN solution and Class Y Caustic Discard solution. The radiological hazard present in the HSSA is Class Y HEU solid. The radionuclide concentrations for the Process Materials are as specified in the *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (21T-02-0300). The Materials at Risk (MAR) for the accident scenarios will be the quantities of material present as summarized in the table below.

U-Al$_x$ Dissolution Process Materials at Risk

Source	Material Description	Quantity	Maximum gU/L	Solubility Class	Physical Form
Drawing 333-A1000-D:					
U-Al$_x$ Storage Rocket	HEU		NA	Y	Solid
P&ID 333-F0406-D (U-Aluminum Dissolution, Sheet 1):					
DISOLV-1A01	HEU		NA	Y	Solid/Slurry
DISOLV-1A11	HEU		NA	Y	Solid/Slurry
ENCLOS-1A06	HEU		NA	Y	Solid
P&ID 333-F0407-D (U-Aluminum Dissolution, Sheet 2):					
DISOLV-1B01	HEU		NA	Y	Solid/Slurry
DISOLV-1B11	HEU		NA	Y	Solid/Slurry
ENCLOS-1B06	HEU		NA	Y	Solid
P&ID 333-F0408-D (U-Aluminum Dissolution, Sheet 3):					
DISOLV-1C01	HEU		NA	Y	Solid/Slurry
DISOLV-1C11	HEU		NA	Y	Solid/Slurry
ENCLOS-1C06	HEU		NA	Y	Solid
P&ID 333-F0409-D (U-Aluminum Dissolution, Sheet 4):					
DISOLV-1D01	HEU		NA	Y	Solid/Slurry
DISOLV-1D11	HEU		NA	Y	Solid/Slurry
ENCLOS-1D06	HEU		NA	Y	Solid
P&ID 333-F0410-D (U-Aluminum Separation, Sheet 5):					
CENTRI-1E01	HEU		NA	Y	Slurry
COLUMN-1E02	HEU		NA	Y	Slurry
CENTRI-1E04	HEU		NA	Y	Slurry
COLUMN-1E05	Caustic Discard		0.05	Y	Liquid
DISOLV-1E09	HEUN		400	D	Liquid
P&ID 333-F0411-D (U-Aluminum Separation, Sheet 6):					
CENTRI-1F01	HEU	L	NA	Y	Slurry
COLUMN-1F02	HEU		NA	Y	Slurry
CENTRI-1F04	HEU	L	NA	Y	Slurry
COLUMN-1F05	Caustic Discard		0.05	Y	Liquid
DISOLV-1F09	HEUN		400	D	Liquid
P&ID 333-F0412-D (U-Aluminum Dissolution Caustic Discard, Bank A, Sheet 7):					
COLUMN-1G01-08	Caustic Discard		0.05	Y	Liquid
P&ID 333-F0413-D (U-Aluminum Dissolution Caustic Discard, Bank B, Sheet 8):					
COLUMN-1H01-08	Caustic Discard		0.05	Y	Liquid
P&ID 333-F0414-D (U-Aluminum Dissolution Accountability Columns, Sheet 9):					
COLUMN-1J01-03	HEUN		400	D	Liquid

[Conservatively assumed each storage rocket contains 7 cans at 7 kg/can with maximum 40% U]
[Conservatively assumed maximum of 2 ingots at 7 kg/ingot with 40% U per dissolver]
[Conservatively assumed]

[Assumed as concentrated heavy metal solution ~30% above projected nominal mass balance value stated in NFS Engineering Project Definition]
[Assumed as aqueous solution at maximum administrative limit as per NCSE]

4.2.3.3 SX Process (Radiological Consequences)

Radiological hazards present in the Solvent Extraction Process include Class D HEUN solution, Class D Raffinate and Class D Condensate. The radionuclide concentrations for the Process Materials are as specified in the *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (21T-02-0300). The Materials at Risk (MAR) for the accident scenarios will be the quantities of material present as summarized in the table below.

SX Process Materials at Risk

Source	Material Description	Quantity	gU/L	Solubility Class	Physical Form
P&ID 333-F0450-D (Solvent Extraction Feed Columns):					
COLUMN 2A01-02	HEUN		[a]400	D	Liquid
P&ID 333-F0451-D (First Pass Extraction):					
COLUMN 2A05	HEUN		[a]400	D	Liquid
COLUMN 2A08	Raffinate		[b]0.05	D	Liquid
COLUMN 2A16	Raffinate		[b]0.05	D	Liquid
COLUMN 2A11	HEUN		[c]14	D	Liquid
P&ID 333-F0452-D (First Pass Solvent Wash):					
COLUMN 2C01	Raffinate		[d]0.15	D	Liquid
COLUMN 2C05	Raffinate		[d]0.15	D	Liquid
P&ID 333-F0453-D (First Pass Evaporator):					
COLUMN 2O11	HEUN		[c]17.5	D	Liquid
COLUMN 2O13	HEUN		[c]17.5	D	Liquid
COLUMN 2O14	HEUN		[a]400	D	Liquid
COLUMN 2O24	HEUN		[a]400	D	Liquid
TANK 2O17	Condensate		[b]0.05	D	Liquid
P&ID 333-F0454-D (SX Interface Solids Filtering):					
COLUMN 2I01	HEUN		[a]400	D	Liquid
P&ID 333-F0455-D (Second Pass Solvent Extraction):					
COLUMN 2B05	HEUN		[a]400	D	Liquid
COLUMN 2B11	HEUN		[c]44.4	D	Liquid
COLUMN 2B16	HEUN		[c]44.4	D	Liquid
P&ID 333-F0456-D (Second Pass Solvent Wash):					
COLUMN 2D01	Raffinate		[d]0.15	D	Liquid
COLUMN 2D05	Raffinate		[d]0.15	D	Liquid
P&ID 333-F0457-D (Second Pass Evaporator):					
COLUMN 2P11	HEUN		[c]66.6	D	Liquid
COLUMN 2P13	HEUN		[a]400	D	Liquid
COLUMN 2P14	HEUN		[a]400	D	Liquid
TANK 2P17	Condensate		[b]0.05	D	Liquid
P&ID 333-F0458-D (First Pass Raffinate Storage):					
COLUMN 2G01-04	Raffinate		[b]0.05	D	Liquid

Source	Material Description	Quantity	gU/L	Solubility Class	Physical Form
P&ID 333-F0459-D (Second Pass Raffinate):					
COLUMN 2H01-03	Raffinate		[d]0.15	D	Liquid
P&ID 333-F0460-D (SX Sump Columns):					
COLUMN 2J01-05	Raffinate		[d]0.15	D	Liquid
P&ID 333-F0461-D (Evaporator Condensate Columns Set A):					
COLUMN 2E01-07	Condensate		[b]0.05	D	Liquid
P&ID 333-F0462-D (Evaporator Condensate Columns Set B):					
COLUMN 2F01-07	Condensate		[b]0.05	D	Liquid
P&ID 333-F0463-D (SX Product Storage Columns):					
COLUMN 2K01-04	HEUN		[a]400	D	Liquid

[a]Assumed as concentrated heavy metal solution ~30% above projected nominal mass balance value (300 gU/L) stated in NFS Engineering Project Definition.
[b]Assumed as aqueous solution at maximum administrative limit
[c]Assumed as concentrated heavy metal solution with concentration at calculated value as provided by SX Area Material Balance 07-June-02
[d]Assumed as aqueous solution with projected concentration as provided by SX Area Material Balance 07-June-02

4.2.3.4 Downblending Process (Radiological Consequences)

Radiological hazards present in the Downblending Process include Class D HEUN solution, Class D LEUN solution, Class D Natural UN solution and Class W UO_3 powder. The radionuclide concentrations for the Process Materials are as specified in the *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (21T-02-0300). The Materials at Risk (MAR) for the accident scenarios will be the quantities of material present as summarized in the table below.

Downblending Process Materials at Risk

Source	Material Description	Quantity	Maximum gU/L	Solubility Class	Physical Form
P&ID 333-F0550-D (Downblending):					
COLUMN 4B01-09	HEUN		[a]400	D	Liquid
COLUMN 4B10	HEUN		[a]400	D	Liquid
TANK 4C01	LEUN		[b]235	D	Liquid
TANK 4C02	Natural UN		[c]500	D	Liquid
P&ID 333-F0551-D (Natural Dissolution):					
DRDUMP 4D01	Natural UO_3		NA	W	Powder
HOPPER 4D02	Natural UO_3		NA	W	Powder
TANK 4D04	Natural UN		[c]500	D	Liquid
P&ID 333-F0552-D (LEUN Transfer):					
TANK 4E01	LEUN		[b]235	D	Liquid
P&ID 333-F0553-D (HEU Mix/Measure Columns):					
COLUMN 4A01-07	HEUN		[a]400	D	Liquid

Source	Material Description	Quantity	Maximum gU/L	Solubility Class	Physical Form
P&ID 333-F0554-D (Natural UN Transfer):					
Tanker	Natural UN		500	D	Liquid

Assumed as concentrated heavy metal solution ~30% above projected nominal mass balance value stated in NFS Engineering Project Definition.
Assumed as concentrated heavy metal solution at upper operating limit as per NRC License (SNM-124), Section 6.5.5, page 10.
Source Material as per license No. S-86001 with assumed maximum concentration well above projected nominal mass balance value stated in NFS Engineering Project Definition.

4.2.3.5 Liquid Waste Discard (Radiological Consequences)

Radiological hazards present in Liquid Discards include Class Y Caustic Waste solution and Class D Condensate. The radionuclide concentrations for the Process Materials are as specified in the *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (21T-02-0300). The Materials at Risk (MAR) for the accident scenarios will be the quantities of material present as summarized in the table below.

Liquid Waste Discard Materials at Risk

Source	Material Description	Quantity	Maximum gU/L	Solublity Class	Physical Form
P&ID 333-F0600-D (BPF Condensate Discharge Tank):					
TANK-5A01	Condensate	[redacted]	0.05	D	Liquid
TANK-5A03	Condensate	[redacted]	0.05	D	Liquid
P&ID 333-F0601-D (BPF Caustic Discharge Tank):					
TANK-5B01	Caustic Discard	[redacted]	0.05	Y	Liquid

Assumed as aqueous solution at maximum administrative limit as per NCSE.

4.2.3.6 Ventilation (Radiological Consequences)

Radiological hazards present in Process Ventilation and Knockout Columns include Class D scrubber solution, Class Y high-enriched uranium (HEU) solution, Class D Raffinate and Class D high-enriched uranyl nitrate (HEUN). The radionuclide concentrations for the process materials are as specified in the *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (21T-02-0300). The materials at risk (MAR) for the accident scenarios will be the quantities of material present as summarized in the table below.

Ventilation Materials at Risk

Source	Material Description	Quantity	Maximum gU/L	Solubility Class	Physical Form
P&ID 333-F0059-D (BPF Process Ventilation, U-Alum Dissolvers):					
COLUMN-6G03	HEU	10 liters	[1]400	Y	Liquid
P&ID 333-F0060-D (BPF Process Ventilation, Sheet 1 of 2):					
COLUMN-6G01	HEU	10 liters	[1]400	Y	Liquid
P&ID 333-F0061-D (BPF Process Ventilation, Sheet 2 of 2):					
COLUMN-6G02	HEU	10 liters	[1]400	Y	Liquid
P&ID 333-F0062-D (BPF Process Scrubber):					
SCRUBR-6H02	Scrubber Soln	500 gal	[2]0.0925 g ^{235}U/L	D	Liquid
TANK-6H05	Scrubber Soln	1,000 gal	[2]0.0925 g ^{235}U/L	D	Liquid
P&ID 333-F0404-D (BPF Nitric Knockout Column):					
COLUMN-3E01	HEUN	56 liters	[1]400	D	Liquid
P&ID 333-F0416-D (BPF Caustic Knockout Column):					
COLUMN-1L01	HEU	24 liters	[1]400	Y	Liquid
P&ID 333-F0466-D (BPF Ventilation Knockout Column):					
COLUMN-2I08	HEUN/Raffinate	56 liters	[1]400	D	Liquid

[1] Conservatively assumed as concentrated heavy metal solution ~30% above projected nominal mass balance value stated in NFS Engineering Project Definition.

[2] Conservatively assumed as aqueous solution at maximum limit as per Nuclear Criticality Safety Evaluation (NCSE) 54T-03-0058.

Table 4-2
Radiological Safety Consequence Analysis Summary (Worker)

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
1	Free-fall Spill HEUN solution SX Area dilution volume	UMM (8.5, 8.10, 8.12, 8.19, 8.36); SXFC (9.3, 9.5, 9.9, 9.11, 9.25, 9.27); SXPS (22.59, 22.61, 22.67, 22.70)	Low
2	Spill (Free-fall and Puncture) HEUN solution SX Area dilution volume	1UMD (1.54, 1.154); 2UMD (2.54, 2.154); 3DT (3.1, 3.2, 3.3, 3.10, 3.11, 3.13, 3.14, 3.18, 3.19, 3.20, 3.21, 3.23, 3.24, 3.25, 3.33, 3.36, 3.37, 3.43, 3.49, 3.50, 3.59); 7DT (4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.14, 4.16, 4.17, 4.19, 4.20, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33, 4.35, 4.36, 4.37, 4.41, 4.45, 4.47, 4.53); UDB (5.3, 5.5, 5.8, 5.13, 5.14, 5.16, 5.18, 5.20, 5.22, 5.24, 5.26, 5.28, 5.30, 5.32, 5.34, 5.44, 5.46, 5.47); UMM (8.1, 8.3, 8.15, 8.16, 8.17, 8.20, 8.22, 8.23, 8.26, 8.35); SXFC (9.13, 9.14, 9.21, 9.22, 9.28, 9.30, 9.31, 9.34, 9.39, 9.44, 9.45, 9.46, 9.47, 9.50, 9.52, 9.53, 9.60, 9.62, 9.64, 9.65); 1PE (12.59, 12.94); 2PE (15.88); SXPS (22.3, 22.5, 22.26, 22.28, 22.30, 22.32, 22.36, 22.38, 22.40, 22.41, 22.43, 22.45, 22.46, 22.47, 22.48, 22.49, 22.50, 22.51, 22.52, 22.53, 22.55, 22.63, 22.72, 22.74, 22.76); UALAC (37.3, 37.5, 37.6, 37.9, 37.10, 37.11, 37.13, 37.16, 37.17, 37.18, 37.28, 37.29, 37.33, 37.38, 37.42, 37.46)	Low
3	Overall Containment Failure HEUN Solution Main Bldg Area dilution volume	3DT (3.52); 7DT (4.48); UDB (5.146); UMM (8.32); UALAC (37.39)	Low
4	Employee Exposure hot HEUN Solution Main Bldg Area dilution volume	1UMD (1.48, 1.50, 1.111, 1.113, 1.114, 1.116, 1.120, 1.134, 1.135); 2UMD (2.48, 2.50, 2.111, 2.113, 2.114, 2.116, 2.120, 2.134, 2.135); 1UALS (33.1, 33.3, 33.5, 33.7, 33.12, 33.13, 33.104); 2UALS (34.1, 34.3, 34.5, 34.7, 34.12, 34.13, 34.102)	Low
5	Employee exposure 2000 gallons Condensate Solution Discard Dike Room dilution volume	ND (26.50, 26.51)	Low
6	Leak in FRNCOV-3A01 U-Metal Main Bldg Area dilution volume	1UMD (1.62, 1.63, 1.64, 1.65, *1.67, 1.68, 1.71, *1.73, 1.74, 1.137, 1.149, 1.164); 2UMD (2.62, 2.63, 2.64, 2.65, *2.67, 2.68, 2.71, *2.73, 2.74, 2.137, 2.149, 2.164)	Low
7	Free-fall Spill U-Metal Main Bldg Area dilution volume	1UMD (1.171); 2UMD (2.171); UMS (39.2, 39.3, 39.5, 39.11, 39.12, 39.13, 39.14, 39.16, 39.17)	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
8	Spill (Free-fall and Puncture) hot HEU Solution Main Bldg Area dilution volume	1UMD (1.1, 1.19, 1.44, 1.47, 1.53, 1.56, 1.59, *1.79, 1.80, *1.82, 1.86, 1.87, 1.106, 1.107, *1.109, 1.124, 1.128, 1.136, 1.147, 1.148, 1.150, 1.152, *1.156, 1.158, 1.162, 1.182) 2UMD (2.1, 2.19, 2.44, 2.47, 2.53, 2.56, 2.59, *2.79, 2.80, *2.82, 2.86, 2.87, 2.106, 2.107, *2.109, 2.124, 2.128, 2.136, 2.147, 2.148, 2.150, 2.152, *2.156, 2.158, 2.162, 2.182)	Low
9	Employee Exposure POG line breach while filling Natural UN tanker	UNT (7.54)	Low
10	Overall Containment Failure 1000 gallons Condensate Solution Discard Dike Room dilution volume	ND 26.26	Low
11	Spill (puncture vs. free-fall) LEUN solution LEU Area dilution volume	UDB (5.78, 5.83, 5.84, 5.91, 5.93, 5.94, 5.97, 5.100, 5.103, 5.150), UNT (7.5, 7.8, 7.12, 7.13, 7.17, 7.19, 7.20, 7.38, 7.45, 7.50, 7.68)	Low
12	Free-fall Spill LEUN Natural UN Natural UN LEU Area dilution volume	UDB (5.55, 5.80, 5.88, 5.116, 5.120, 5.129)	Low
13	Spill (Free-fall and puncture) hot NUN LEU Area dilution volume	UDB (5.52, 5.54, 5.57, 5.128), UND (6.39, 6.41, 6.46, 6.62, 6.66, 6.69, 6.71, 6.72, 6.80, 6.81, 6.84, 6.100, 6.101, 6.102, 6.104, 6.106, 6.110, 6.176, 6.177, 6.179, 6.184, 6.186, 6.188, 6.189, 6.190, 6.193, 6.196, 6.199, 6.211, 6.212, 6.221, 6.227, 6.228, 6.235, 6.236, 6.237, 6.238, 6.241, 6.242, 6.243, 6.261, 6.265, 6.266, 6.268, 6.272, 6.273, 6.280, 6.281, 6.283), UNT (7.31, 7.37, 7.41, 7.42, 7.47)	Low
14	Spill (Free-fall and Puncture) 2000 gallons Condensate Solution Discard Dike Room dilution volume Plus 1820 L Condensate Solution SX Area dilution volume	ECA (20.2, 20.4, 20.5, 20.7, 20.8, 20.10, 20.11), ECB (21.1, 21.3, 21.4, 21.6, 21.7), ND (26.1, 26.2, 26.4, 26.12, 26.21, 26.23, 26.24, 26.27, 26.31, 26.32, 26.39, 26.41, 26.42, 26.43, 26.46)	Low
15	Overall Containment Failure NUN LEU Area dilution volume	UDB 5.140 UND (6.59, 6.60, 6.225)	Low
16	Employee exposure LEUN/ NUN LEU Area dilution volume	UDB (5.139, 5.141, 5.142, 5.143) UNT (7.23, 7.24, 7.56)	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
17	Drum Lift Hydraulic System Fails Hydraulic Fluid Fire Drum Free-fall powder spill LEU Area dilution volume	UND (*6.1; *6.2; *6.3; *6.5; *6.6; *6.7; *6.8; *6.9; *6.10; *6.11; *6.12; *6.18; *6.20; *6.21)	Low
18	Spill (Free-fall vs puncture) Natural UN Outside dilution volume	UNT (7.39; 7.44)	Low
19	Employee exposure 760L Caustic Waste Solution Main Bldg Area dilution volume	1UALC (35.42); 2UALC (36.42)	Low
20	Free fall spill natural UO_3 powder LEU Area dilution volume	UND (*6.22; *6.23; 6.26; *6.35; 6.278; 6.279; 6.282; 6.285; 6.286)	Low
21	Employee exposure HEUN Solution Main Bldg Area dilution volume	3DT (3.46; 3.47; 3.53); 7DT (4.49); UDB (5.147); UMM (8.33); UALAC (37.36; 37.37; 37.40)	Low
22	Employee exposure hot NUN LEU Area dilution volume	UND (6.68; 6.158; 6.165; 6.172; 6.187; 6.224; 6.226; 6.233)	Low
23	Excessive Exothermic Rx Natural UN LEU Area dilution volume	UND (*6.27; *6.29; 6.30; *6.32; 6.63; 6.64)	Low
24	Resuspension (POG plug) Natural UO_3 powder LEU Area dilution volume	UND (6.25; 6.246; 6.289)	Low
25	Employee exposure Externally contaminated container Bldg 306-W dilution volume	UMS 39.8	Low
26	Overall Containment Failure LEUN LEU Area dilution volume	UDB 5.138 UNT 7.22	Low
27	Spill (Free-fall and Puncture) Solution UNB Storage Area dilution volume	UNT (7.25; 7.35; 7.51)	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
28	Overall Containment Failure NUN Outside dilution volume	UNT (7.3; 7.53)	Low
29	Employee Exposure 1,000 gallons Scrubber Solution Discard Dike Area dilution volume	PS (45.143; 45.144)	Low
30	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
31	Spill 7 cans U-Al x ingots Main Bldg Area dilution volume	HSSA (28.7; 28.13; 28.14; 28.15; 28.16)	Low
32	Overall Containment Failure 1000-gallons Caustic Waste Solution Discard Dike Room dilution volume	CD (27.26)	Low
33	Spill (Free-fall and Puncture) 1,500 gallons Scrubber Solution Discard Dike Area dilution volume	PS (45.5; 45.7; 45.11; 45.13; 45.17; 45.19; 45.21; 45.25; 45.33; 45.46; 45.60; 45.64; 45.66; 45.70; 45.75; 45.78; 45.79; 45.80; 45.81; 45.83; 45.84; 45.87; 45.88; 45.89; 45.91; 45.92; 45.95; 45.96; 45.101; 45.106; 45.107; 45.112; 45.126; 45.136; 45.138; 45.142)	Low
34	Red Oil Incident	1PX (10.2; 10.55; 10.57; 10.63); 1PE (12.88; 12.90; 12.92; 12.185; 12.186; 12.187); 2PSX (13.35; 13.37; 13.41; 13.71; 13.90); 2PE (15.82; 15.84; 15.86; 15.155; 15.156; 15.157)	High
35	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
36	Overall Containment Failure HEUN Solution SX Area dilution volume	SXFC 9.37; SXPS 22.34	Low
37	Employee Exposure HEUN SX Area dilution volume	SXFC 9.38; 1PX 10.129; 2PSX 13.86; SXSF (16.14; 16.27; 16.28; 16.29); SXPS 22.35	Low
38	Employee Exposure 1000 gallons Caustic Waste Solution Discard Dike Room dilution volume	CD (27.48; 27.49)	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
39	Spill (Free-fall and Puncture) SX Process Source Term SX Area dilution volume	1PX (10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.56, 10.58, 10.59, 10.60, 10.61, 10.62, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.74, 10.75, 10.76, 10.77, 10.78, 10.80, 10.81, 10.82, 10.83, 10.84, 10.85, 10.86, 10.88, 10.89, 10.90, 10.91, 10.92, 10.94, 10.95, 10.96, 10.97, 10.98, 10.99, 10.100, 10.103, 10.104, 10.105, 10.106, 10.107, 10.108, 10.109, 10.110, 10.112, 10.119, 10.122, 10.124, 10.126), 1PSW (11.1, 11.2, 11.3, 11.6, 11.8, 11.10, 11.11, 11.12, 11.13, 11.14, 11.22, 11.24, 11.25, 11.26, 11.27, 11.28, 11.30, 11.40, 11.41, 11.48, 11.49, 11.50, 11.51, 11.52, 11.53, 11.54, 11.55, 11.56, 11.57, 11.58, 11.59, 11.60, 11.61, 11.62, 11.63, 11.65, 11.67, 11.68, 11.69, 11.70, 11.71, 11.73, 11.74, 11.75, 11.77, 11.78, 11.79, 11.80, 11.82, 11.83, 11.84, 11.85, 11.89, 11.90, 11.91, 11.92, 11.93, 11.94, 11.95, 11.99, 11.101, 11.102, 11.103, 11.106, 11.107, 11.112, 11.114), 1PE 12.128, 2PSX (13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.36, 13.38, 13.39, 13.40, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.50, 13.51, 13.52, 13.53, 13.54, 13.56, 13.57, 13.58, 13.59, 13.60, 13.62, 13.63, 13.64, 13.65, 13.66, 13.67, 13.68, 13.69, 13.70, 13.75, 13.77, 13.82, 13.84, 13.89, 13.91, 13.93), 2PSW (14.1, 14.2, 14.6, 14.8, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.25, 14.26, 14.27, 14.28, 14.30, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.57, 14.58, 14.59, 14.60, 14.61, 14.62, 14.63, 14.65, 14.67, 14.68, 14.69, 14.70, 14.71, 14.73, 14.74, 14.75, 14.77, 14.78, 14.79, 14.80, 14.82, 14.83, 14.84, 14.85, 14.89, 14.90, 14.91, 14.92, 14.93, 14.94, 14.95, 14.99, 14.101, 14.102, 14.103, 14.106, 14.108, 14.110, 14.111), 2PE 15.102, SXSF (16.1, 16.9, 16.15, 16.16, 16.19, 16.31, 16.37, 16.39, 16.40, 16.41, 16.44, 16.45, 16.52, 16.55, 16.57, 16.59), 1PRS (17.3, 17.5, 17.9, 17.11, 17.14, 17.15, 17.19, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.32, 17.33, 17.34, 17.45, 17.47, 17.51, 17.57, 17.65, 17.76, 17.79, 17.82, 17.85), 2PRS (18.2, 18.9, 18.11, 18.12, 18.14, 18.16, 18.17, 18.18, 18.19, 18.22, 18.29, 18.30, 18.33, 18.34, 18.35), SXSC (19.5, 19.9, 19.11, 19.12, 19.14, 19.15, 19.20), ECA (20.17, 20.40, 20.41, 20.43), ECB (21.13, 21.36, 21.37, 21.39), 1SXCM (23.34, 23.55), 2SXCM (24.2, 24.7, 24.16, 24.18, 24.20, 24.22, 24.52), VKC (25.3, 25.5, 25.6), UTD (40.26, 40.28, 40.32)	Low
40	Spill (Free-fall and Puncture) 1000 gallons Caustic Waste Solution Discard Dike Room dilution volume Plus 1520L Caustic Waste Solution Main Bldg Area dilution volume	CD (27.1, 27.2, 27.4, 27.12, 27.21, 27.24, 27.27, 27.31, 27.32, 27.39, 27.41, 27.42, 27.43, 27.54), 1UALS (33.45, 33.46, 33.47, 33.48, 33.49, 33.50, 33.51), 2UALS (34.45, 34.46, 34.47, 34.48, 34.49, 34.50, 34.51), 1UALC (35.3, 35.7, 35.8, 35.9, 35.12, 35.13, 35.14, 35.16, 35.19, 35.20, 35.21, 35.25, 35.34, 35.36, 35.40, 35.44, 35.48, 35.51, 35.59), 2UALC (36.3, 36.7, 36.8, 36.9, 36.12, 36.13, 36.14, 36.16, 36.17, 36.19, 36.20, 36.21, 36.25, 36.34, 36.36, 36.40, 36.48, 36.51, 36.59)	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
41	Overall Containment Failure 760L Caustic Waste Solution Main Bldg Area dilution volume	1UALC 35.41; 2UALC 36.41	Low
42	Spill (Free-fall and Puncture) hot HEUN Solution 1820L Condensate Solution SX Area dilution volume	1PE (12.24, 12.26, 12.30, 12.32, 12.34, 12.45, 12.52, 12.55, 12.56, 12.60, 12.61, 12.62, 12.63, 12.64, 12.65, 12.66, 12.67, 12.68, 12.69, 12.70, 12.72, 12.73, 12.74, 12.75, 12.79, 12.80, 12.81, 12.82, 12.83, 12.95, 12.100, 12.102, 12.103, 12.106, 12.107, 12.108, 12.110, 12.113, 12.114, 12.115, 12.116, 12.117, 12.118, 12.120, 12.121, 12.122, 12.130, 12.167, 12.179); 2PE (15.24, 15.26, 15.30, 15.32, 15.34, 15.47, 15.50, 15.51, 15.54, 15.55, 15.56, 15.57, 15.58, 15.59, 15.60, 15.61, 15.62, 15.63, 15.64, 15.66, 15.67, 15.68, 15.69, 15.73, 15.74, 15.75, 15.76, 15.77, 15.89, 15.92, 15.94, 15.95, 15.96, 15.98, 15.99, 15.100, 15.104, 15.141, 15.153)	Low
43	Overall Containment Failure 2nd Pass Raffinate Solution SX Area dilution volume	1PRS 17.61; 2PRS 18.26; SXSC 19.22	Low
44	Employee exposure 2nd Pass Raffinate Solution SX Area dilution volume	1PSW 11.116; 2PSW 14.116; 1PRS 17.62; 2PRS 18.27; SXSC 19.23	Low
45	Overall Containment Failure 910L Condensate Solution SX Area dilution volume	ECA 20.31; ECB 21.27	Low
46	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
47	Employee exposure boiling HEUN Solution hot HEUN Solution room temp HEUN Solution SX Area dilution volume	1PE (12.28, 12.85, 12.89, 12.91, 12.99, 12.132); 2PE (15.28, 15.79, 15.83, 15.85, 15.91, 15.106)	Low
48	Employee exposure 910 liters Condensate Solution SX Area dilution volume	ECA 20.32; ECB 21.28	Low
49	Loss of Cooling Water to Plant Processes resulting in Exposure at Source Points	UTD (40.1, 40.2, 40.4, 40.7)	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
50	Spill (Free-fall and Puncture) hot HEUN Main Bldg Area dilution volume	1UALS (33.10, 33.14, 33.16, 33.19, 33.21, 33.58, 33.62, 33.66, 33.69, 33.71, 33.74, 33.75, 33.77, 33.87, 33.89, 33.90, 33.95, 33.97, 33.109) 2UALS (34.10, 34.14, 34.16, 34.19, 34.21, 34.55, 34.59, 34.62, 34.64, 34.67, 34.68, 34.70, 34.80, 34.82, 34.83, 34.88, 34.90, 34.96, 34.107)	Low
51	Loss of Ventilation Resulting in Exposure at Source Points	PV (44.2, 44.3, 44.5, 44.7, 44.9, 44.11, 44.17, 44.18, 44.20, 44.21, 44.23, 44.24); PS (45.31, 45.34, 45.38, 45.40, 45.41, 45.52, 45.111)	Low
52	Spill (Free-fall and Puncture) Hot Class Y HEU ( ) Main Bldg Area dilution volume	1UALD (*29.16, 29.20, 29.22, 29.27, *29.31, *29.33, *29.35, 29.46, *29.63, *29.64, *29.76, 29.77, 29.89, 29.91); 2UALD (*30.16, 30.20, 30.22, 30.27, *30.31, *30.33, *30.35, 30.46, *30.63, *30.64, *30.76, 30.77, 30.89, 30.91); 3UALD (*31.16, 31.20, 31.22, 31.27, *31.31, *31.33, *31.35, 31.46, *31.63, *31.64, *31.76, 31.77, 31.89, 31.91); 4UALD (*32.16, 32.20, 32.22, 32.27, *32.31, *32.33, *32.35, 32.46, *32.63, *32.64, *32.76, 32.77, 32.89, 32.91); 1UALS (*33.24, 33.27, 33.28, 33.29, 33.33, 33.34, 33.35, 33.36, 33.37, 33.39, 33.40, 33.41, 33.42, 33.43, 33.107, 33.108, 33.111); 2UALS (*34.24, 34.27, 34.28, 34.29, 34.33, 34.34, 34.35, 34.36, 34.37, 34.39, 34.40, 34.41, 34.42, 34.43, 34.105, 34.106, 34.109); PV 44.14	Low
53	Vented Hydrogen Explosion into POG	1UALD (29.23, 29.25, 29.26, 29.30, 29.45, 29.48, 29.49, 29.66, 29.70, 29.78, 29.80, 29.84, 29.88); 2UALD (30.23, 30.25, 30.26, 30.30, 30.45, 30.48, 30.49, 30.66, 30.70, 30.78, 30.80, 30.84, 30.88); 3UALD (31.23, 31.25, 31.26, 31.30, 31.45, 31.48, 31.49, 31.66, 31.70, 31.78, 31.80, 31.84, 31.88); 4UALD (32.23, 32.25, 32.26, 32.30, 32.45, 32.48, 32.49, 32.66, 32.70, 32.78, 32.80, 32.84, 32.88) CMST (38.16, 38.17, 38.18, 38.19, 38.20, 38.31, 38.32, 38.33, 38.34, 38.36, 38.47); UTD (40.9, 40.12, 40.16)	Low
54	Employee exposure U-Metal Main Bldg Area dilution volume	1UMD (1.76, 1.138) 2UMD (2.76, 2.138)	Low
55	Employee Exposure Hot Class Y HEU ( ) Main Bldg Area dilution volume	1UALD (*29.68); 2UALD (*30.68); 3UALD (*31.68); 4UALD (*32.68)	Low
56	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
57	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
58	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
59	Spill (free-fall/puncture) hot Raffinate Discard solution/slurry/polymer Discard Dike Area dilution volume	1PRS (17.77, 17.83)	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
60	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
61	INTENTIONALLY LEFT OPEN FOR FUTURE USE		
NA	Inadvertent transfer to waste water treatment facility	ND 26.37; CD 27.37 UTD (40.49; 40.50; 40.52; 40.56); PV (44.1; 44.22); PS (45.10; 45.14; 45.22; 45.24; 45.26; 45.28; 45.29; 45.32; 45.67; 45.109; 45.127)	
NA	Environmental release of contamination		

Note: Likelihood of fire/explosion deemed not credible by Fire Protection Safety Evaluation; therefore not included as part of scenario.
Note: Fire Protection Safety Evaluation (21T-03-1099) states, "The low heat output would not be expected to damage the enclosures or metal equipment or containers."
Note: Unshielded cart scenario conservatively bound by free fall spill of U metal (ARF is 0 for free-fall spill of metal, therefore the only contribution to dose is the external component)
Note: Consequence bound by Waste Water Treatment ISA; therefore consequence evaluation (BPF) not performed.
Note: Assumed designation of High Consequence based on inherent severity of Red Oil Incident.
Note: Initiating Event for fires deemed highly unlikely as per Fire Protection Accident Consequence Evaluations for Solvent Extraction Process in BLEU Prep Facility (BPF) ISA (21T-03-1184)
Note: No safety concern from an occupational health physics standpoint; therefore consequence evaluation not performed.
Note: Initiating Event for diesel fire (UNT-7-43) deemed not credible as per Fire Protection Accident Consequence Evaluations for Downblending Process in BLEU Prep Facility (BPF) ISA (21T-03-1035)

4.2.4 Fire Safety Consequence Analysis

Fire hazards for the BPF were evaluated through the Fire Hazards Analysis (FHA) (Reference 10), and through an unmitigated fire or explosion damage assessment for specific What-If scenarios from the PHA. The hazards and controls determined through the FHA for the BPF are summarized in the Fire Hazard Sections of Section 3 (3.1.2.4, 3.2.2.4, etc.). Each process in Section 3 identifies Fire and Explosion hazards, along with the required controls, as determined by the FHA. For the What-If scenarios identified by the PHA process, unmitigated fire and explosion damage assessments were performed to provide baseline conditions to determine radiological and chemical exposures. Once the baseline fire and explosion damage conditions were defined, separate consequence evaluations were performed to determine chemical, radiological, and environmental consequences. The methodology and results of the chemical, radiological, and environmental consequence analyses are reported in the appropriate consequence section. These fire scenarios were also evaluated in the Nuclear Criticality Safety Evaluations (NCSEs).

The attached Fire Safety Consequence Analysis Summary Table identifies the fire and explosion scenarios that were evaluated based on the What-If accident sequences from the PHA. As indicated in the table, for credible fire or explosion scenarios the exposure consequences are determined by the other safety disciplines (chemical, radiological, and environmental) and reported in the appropriate consequence summary tables.

Table 4-3
Fire and Explosion Consequence Analysis Summary

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		U Metal	
1	Potential fire or explosion from HEATER-3A04/3B04 or FRNCOV-3A01/3B01; Potential explosion; Potential for adverse chemical reaction in heated furnace (explosion)	1UMD-1.67, 1.73, 1.79, 1.82, 1.109, and 1.156 2UMD-2.67, 2.73, 2.79, 2.82, 2.109 and 2.156	Not Credible
2	Potential flash fire; Potential fire in glovebox; Potential to ignite a larger U-Metal coupon	1UMD-1.164 2UMD-2.164	See Safety Disciplines Evaluations
		U Metal Sampling	
1	Potential flash fire; Potential fire in glovebox; Potential to ignite a larger U-Metal coupon	UMS-39.13, 39.16.a, and 39.16.b	See Safety Disciplines Evaluation
		U-Aluminum Dissolution	
1	Potential explosion from vented hydrogen into POG; Potential loss of inert atmosphere resulting in a potential explosion	1UALD-29.16 and 29.76; 2UALD-30.16 and 30.76; 3UALD-31.16 and 31.76; 4UALD-32.16 and 32.76	No Safety Concern As a Single Failure Event
2	Potential for loss of inert atmosphere resulting in a potential explosion; Potential explosion from vented hydrogen into POG	1UALD-29.23, 29.25, 29.26, 29.30, 29.78, 29.80 and 29.88 2UALD-30.23, 30.25, 30.26, 30.30, 30.78, 30.80 and 30.88 3UALD-31.23, 31.25, 31.26, 31.30, 31.78, 31.80 and 31.88 4UALD-32.23, 32.25, 32.26, 32.30, 32.78, 32.80 and 32.88 CMST-38.16, 38.17, 38.18, 38.19, 38.20, 38.31, 38.32, 38.33, 38.34, 38.36 and 38.47	See Safety Disciplines Evaluations
3	Potential explosion from vented hydrogen into room; Potential explosion due to hydrogen build-up during dissolution	1UALD-29.31, 29.35, 29.63, 29.64 and 29.68 2UALD-30.31, 30.35, 30.63, 30.64 and 30.68 3UALD-31.31, 31.35, 31.63, 31.64 and 31.68 4UALD-32.31, 32.35, 32.63, 32.64 and 32.68	Not Credible
4	Potential explosion	1UALD-29.33; 2UALD-30.33; 3UALD-31.33; 4UALD-32.33	Not Credible

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
5	Potential explosion from vented hydrogen into POG; Potential explosion from vented hydrogen into ENCLOS-1A06 / 1B06 / 1C06 / 1D06; Potential explosion due to hydrogen buildup during dissolution	1UALD-29.45; 29.48; 29.49; 29.66; 29.70 and 29.84 2UALD-30.45; 30.48; 30.49; 30.66; 30.70 and 30.84 3UALD-31.45, 31.48; 31.49; 31.66; 31.70 and 31.84 4UALD-32.45; 32.48; 32.49; 32.66; 32.70 and 32.84	See Safety Disciplines Evaluations
6	Potential fire due to pyrophoric dry UO_2 formation in centrifuge	1UALS-33.24 2UALS-34.24	Not Credible
		High Security Storage Area	
1	No identified scenarios.	Not Applicable	Not Applicable

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		Solvent Extraction	
1	Potential fire; Potential for fire	1PSX-10.2.a, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55.a, 10.56, 10.58, 10.59, 10.60, 10.61, 10.62, 10.63.a, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.75, 10.77, 10.78, 10.80, 10.81, 10.83, 10.85, 10.86, 10.88, 10.89, 10.91, 10.94, 10.95, 10.96, 10.97, 10.99, 10.103, 10.104, 10.105, 10.107, 10.109, 10.110, 10.112, 10.116, 10.119, 10.122, 10.124, and 10.126 1PSW-11.6, 11.10, 11.11, 11.12, 11.13, 11.14, 11.22, 11.24, 11.28, 11.30, 11.40, 11.41, 11.48, 11.49, 11.50, 11.51, 11.52, 11.53, 11.54, 11.55, 11.56, 11.58, 11.60, 11.62, 11.65, 11.67, 11.68, 11.69, 11.70, 11.73, 11.74, 11.77, 11.78, 11.80, 11.82, 11.84, 11.85, 11.90, 11.106, 11.112 and 11.114 1PE-12.88.b, 12.90.b, 12.92.b, 12.185.b, 12.186.b and 12.187.b 2PSX-13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.35.a, 13.36, 13.38, 13.39, 13.40, 13.41.a, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.51, 13.53, 13.54, 13.56, 13.57, 13.59, 13.62, 13.63, 13.64, 13.65, 13.67, 13.69, 13.70, 13.71.b, 13.75, 13.77, 13.80, 13.82, 13.84, 13.89, 13.90, 13.91 and 13.93 2PSW-14.6, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.28, 14.30, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.58, 14.60, 14.62, 14.65, 14.67, 14.68, 14.69, 14.70, 14.73, 14.74, 14.77, 14.78, 14.80, 14.82, 14.84, 14.85, 14.90, 14.106, 14.108 and 14.110 2PE-15.82.b, 15.84.b, 15.86.b, 15.155.b, 15.156.b and 15.157.b 1PRS-17.3, 17.5, 17.9, 17.11, 17.19, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.33, 17.45, 17.47, and 17.65 2PRS-18.2, 18.9, 18.11, 18.12, 18.14, 18.16, 18.18, 18.22, 18.29 and 18.33 SXSC-19.5, 19.9, 19.11, 19.12, 19.14 and 19.20 ECA-20.17 ECB-21.13 1SXCM-23.24, 23.55 and 23.82 VKC-25.3, 25.5 and 25.6	Initiating Event is Highly Unlikely
2	Potential for solvent to enter COLUMN-2O11 (red oil); Potential fire (red oil); Potential for solvent to enter COLUMN-2P11 (red oil); Potential Red Oil accident	1PSX-10.2.b, 10.55.b, 10.57.a, 10.57.b, and 10.63.b 1PE-12.88.a, 12.90.a, 12.92.a, 12.185.a, 12.186.a and 12.187.a 2PSX-13.35.b, 13.37.a, 13.37.b, 13.41.b, 13.71.a, and 13.90.a 2PE-15.82.a, 15.84.a, 15.86.a, 15.155.a, 15.156.a and 15.157.a	See Safety Disciplines Evaluations

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
3	Potential fire	1PSW-11.2, 11.25, 11.26, 11.27, 11.91, 11.92, 11.94, 11.99, 11.101, 11.102, and 11.103 2PSW-14.2, 14.25, 14.26, 14.27, 14.91, 14.92, 14.94, 14.99, 14.101, 14.102 and 14.103	Initiating Event Is Highly Unlikely
4	Potential fire	1SXCM-23.7, 23.8, 23.10, 23.12, 23.13, 23.18, 23.19, 23.20, 23.22, 23.26, 23.27, 23.34, 23.36, 23.37, 23.38, 23.39, 23.40, 23.41, 23.42 and 23.86	Initiating Event Is Highly Unlikely
5	Potential fire (nitric acid into solvent)	2SXCM-24.2, 24.7 and 24.52	No Safety Concern
6	Potential fire	2SXCM-24.16, 24.18, 24.20 and 24.22	Initiating Event Is Highly Unlikely
		Downblending	
1	Potential dust explosion hazard; Potential oxide fire	UND-6.1, 6.2, 6.3, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11, 6.12, 6.18, 6.20.b, 6.21.b, 6.22, 6.23, 6.27, 6.29, 6.32 and 6.35	Not credible
2	Potential fire	UND-6.20.a and 6.21.a	See Safety Disciplines Evaluation
3	Potential for fire to spread to other structures	UND-7.43	See Safety Disciplines Evaluation
		Liquid Waste Discard	
1	No identified scenarios requiring evaluation	ND/CD	N/A
		Ventilation	
1	Potential explosion due to build up of hydrogen at source points; Potential fire due to blowing hydrogen fumes into the workspace	P.V-44.3 and 44.21	Bounded by Scenario #5 in U-Aluminum Process
		Utilities	
1	No identified scenarios requiring evaluation	UTD	N/A

4.2.5 Environmental Safety Consequence Analysis

The BPF environmental safety consequences are divided into two sections: Environmental Chemical Safety and Environmental Radiological Safety. The following environmental chemical and radiological analyses determine exposure to the public from credible BPF accident scenarios.

4.2.5.1 Environmental Chemical Safety Consequence Analysis

A Process Hazards Analysis was performed on the BPF in accordance with NFS-GH-55 (Integrated Safety Analysis) by an ISA team. The analysis identified the hazards associated with each area of the BPF by using the "What-If-Table" methodology. The chemical and radiological hazards were evaluated to identify credible accident sequences resulting from a single upset event and the control needed to prevent or limit their occurrence or mitigate their potential consequence. A quantitative estimate of the potential consequences resulting from each accident was analyzed. Each credible accident scenario was assigned an unmitigated, uncontrolled consequence severity category based on 10 CFR 70.61 as follows:

- High Consequence – An individual at the Controlled Area boundary receiving a concentration in excess of the ERPG-2 Limit;
- Intermediate Consequence - An individual at the Controlled Area boundary receiving a concentration greater than the ERPG-1 Limit, but less than or equal to the ERPG-2 Limit; and
- Low Consequence – An individual at the Controlled Area boundary receiving a concentration less than or equal to the ERPG-1 Limit.

The risks associated with each intermediate or high consequence accident were evaluated in accordance with NFS-HS-A-68 (ISA Risk Assessment Program). Risk assessments were performed to determine the engineered controls and administrative controls or both that are necessary to reduce the likelihood of the accident event.

Consequence Analysis Methodology

Emergency Response Planning Guidelines (ERPG), published by the American Industrial Hygiene Association (AIHA) were used to estimate the concentration ranges above which acute exposure would be expected to lead to adverse heath effects (ERPG-1 and ERPG-2). ERPG-1 and ERPG-2 action levels are applicable to individuals outside the control area boundary. Where ERPG limits were not available Temporary Emergency Exposure Guidelines (TEEL), published by the DOE Emergency Management Advisory Committee's Subcommittee on Consequence Assessment and Protective Actions (SCAPA) were used. TEEL-1 and TEEL-2 limits are applicable to individuals outside the control area boundary.

Chemical environmental consequences were evaluated using the Arial Locations of Hazardous Atmosphere (ALOHA) model (windows version 5.2.3). ALOHA is an air dispersion modeling program designed to predict the rate at which chemical vapors escape into the atmosphere and disperses. The ALOHA model uses a Gaussian dispersion model to estimate plume concentration when the source strength is known or estimated. The puddle model option was used to estimate the consequence associated with pure chemicals. The direct model option was used to estimate the consequences of chemicals that are less than 100% concentration. When using the direct model option, a general vapor generation model (Estimating Releases and Waste Treatment Efficiencies for Toxic Chemical Release Inventory Form, EPA 560 4-88-002, 12/87) was used to estimate the vaporization rate of dilute chemical mixtures.

The spill duration of one (1) hour is used by ALOHA, which is assumed to correspond to the ERPG limit for a one (1) hour exposure. The volume of the bounding spill was calculated assuming an average spill depth of 0.0328 ft. for outdoor spills (NUREG-6410, B.2.2, page B-24) and 0.3332 ft (Threshold on north and west doors inside Building 333) for indoor spills.

The source terms were defined by the physical properties of each chemical considered and the concentrations defined by the process specific information. Material Safety Data Sheets (MSDS), Perry's Chemical and Engineering Handbook, CRC Handbook of Chemical and Physical Properties, and the TEEL Database were used in defining the physical properties used in consequence analysis. Maximum emission values from the request for an air pollution construction permit were used to evaluate failures of the process scrubber and ventilation system. In all cases, ALOHA was used to model vapor dispersion.

This approach allows for consideration of chemical vapor pressure changes due to lower chemical concentrations and results in chemical specific bounding spill volumes for each ERPG or TEEL level. Accident sequences were grouped as appropriate according to maximum spill volume and chemical concentration.

For scenarios that involve outdoor spills of dissolved solids, the calculation will be based on the five-factor formula defined in NUREG/CR-6410 and supplemented as necessary with guidance provided in DOE-HDBK-3010-94 *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities.*

4.2.5.1.1 UAl Dissolution Process (Environmental Chemical Consequences)

Potential chemical airborne releases can occur from the following type of accidents:

- Mechanical Stress
- Thermal Stress

- Explosive and Energetic Events
- Human Error

The consequence of the above accident events is a release of chemical material inside Building [redacted] Chemical material released inside the dissolution process area in excess of the dissolution area containment volume will be released to the outside environment. These chemical vapors provide the pathway for acute or chronic chemical exposure to individuals at the control area boundary.

The following chemicals are used in the dissolution process area:

- Nitric Acid (67%)
- Hydrogen Peroxide
- Sodium Hydroxide
- Sodium Nitrate
- Barium Nitrate
- Sodium Carbonate (5%)
- Ammonia
- Nitric Oxide

The consequence of releasing the above chemicals outside of containment was evaluated to determine the extent of exposure to individuals at the control area boundary. Consequence assessments were performed on these chemical releases using the ALOHA model, vapor generation model, and a bounding spill depth calculation. The assumptions and methodology used in these assessments are identified in Table 4-6 (Environmental Safety Chemical Assumptions for Scenario Development). The quantitative results of the chemical assessments were used to estimate the concentration ranges above which acute exposure would be expected to lead to adverse health effects (ERPG and TEEL limits) at the control area boundary.

The risk associated with each intermediate and high consequence event related to the release of these chemicals was evaluated. The margin of safety necessary to reduce exposure to individuals at the control area boundary to below the ERPG and/or TEEL limits is provided by engineered controls, administrative controls, or both dependent upon the extent necessary. The following general controls have been identified for the dissolution area:

- Materials of construction
- Process Interlocks
- Dike containment
- Scrubber
- Procedures and Training

The measures applied to a particular engineered or administrative control or control system will be commensurate with the risk reduction attributed to the control or control system.

4.2.5.1.2 SX Process (Environmental Chemical Consequences)

Potential chemical airborne releases can occur from the following type of accidents:

- Mechanical Stress
- Thermal Stress
- Explosive and Energetic Events
- Human Error

The consequence of the above accident events is a release of chemical material inside Building [redacted] Chemical material released inside the solvent extraction process area in excess of the solvent extraction area containment volume will be released to the outside environment. These chemical vapors provide the pathway for acute or chronic chemical exposure to individuals at the control area boundary.

The following chemicals are used in the solvent extraction process area:

- Nitric Acid (67%)
- Normal paraffin hydrocarbon (Norpar-12)
- Tributyl Phosphate (TBP)
- Sodium Carbonate, Sodium Hydroxide, Sodium Nitrate, Barium Nitrate

The consequence of releasing the above chemicals outside of containment was evaluated to determine the extent of exposure to individuals at the control area boundary. Consequence assessments were performed on these chemical releases using the ALOHA model, vapor generation model, and a bounding spill depth calculation. The assumptions and methodology used in these assessments are identified in **Table 4-6** (Environmental Safety Chemical Assumptions for Scenario Development). The quantitative results of the chemical assessments were used to estimate the concentration ranges above which acute exposure would be expected to lead to adverse health effects (ERPG and TEEL limits) at the control area boundary.

The risk associated with each intermediate and high consequence events related to the release of these chemicals was evaluated. The margin of safety necessary to reduce exposure to individuals at the control area boundary to below the ERPG and/or TEEL limits is provided by engineered controls, administrative controls, or both dependent upon the extent necessary. The following general controls have been identified for the solvent extraction area:

- Materials of construction
- Process Interlocks
- Dike containment
- Scrubber
- Procedures and Training

The measures applied to a particular engineered or administrative control or control system will be commensurate with the risk reduction attributed to the control or control system.

4.2.5.1.3 Downblending Process (Environmental Chemical Consequences)

Potential chemical airborne releases can occur from the following type of accidents:

- Mechanical Stress
- Thermal Stress
- Explosive and Energetic Events
- Human Error

The consequence of the above accident events is a release of chemical material inside Building [redacted] Chemical material released inside the downblending area in excess of the downblending area containment volume will be released to the outside environment. These chemical vapors provide the pathway for acute or chronic chemical exposure to individuals at the control area boundary.

The following chemicals are used in the downblending process:

- Nitric Acid (67%)
- Uranyl Nitrate ( )

The consequence of releasing the above chemicals outside of containment was evaluated to determine the extent of exposure to individuals at the control area boundary. Consequence assessments were performed on these chemical releases using the ALOHA model, vapor generation model, and a bounding spill depth calculation. The assumptions and methodology used in these assessments are identified in **Table 4-6** (Environmental Safety Chemical Assumptions for Scenario Development). The quantitative results of the chemical assessments were used to estimate the concentration ranges above which acute exposure would be expected to lead to adverse health effects (ERPG and TEEL limits) at the control area boundary.

The risk associated with each intermediate and high consequence event related to the release of these chemicals was evaluated. The margin of safety necessary to reduce exposure to individuals at the control area boundary to below the ERPG

and/or TEEL limits is provided by engineered controls, administrative controls, or both dependent upon the extent necessary. The following general controls have been identified for the downblending area:

- Materials of construction
- Process Interlocks
- Dike containment
- Scrubber
- Procedures and Training

The measures applied to a particular engineered or administrative control or control system will be commensurate with the risk reduction attributed to the control or control system.

4.2.5.1.4 Bulk Chemical Storage (Environmental Chemical Consequences)

Potential chemical airborne releases can occur from the following type of accidents:

- Mechanical Stress
- Thermal Stress
- Explosive and Energetic Events
- Human Error

The consequence of the above accident events is a release of chemicals to the outside environment. The release of bulk chemicals outside of containment provides the pathway for acute or chronic chemical exposure to individuals at the control area boundary.

The following chemicals are used in the BPF area and are stored in bulk quantities at the Bulk Chemical Tank Farm:

- Nitric Acid (67%)
- Normal paraffin hydrocarbon (Norpar-12)
- Trybutyl Phosphate (TBP)
- Sodium Hydroxide
- Hydrogen Peroxide

The consequence of releasing the above chemicals outside of containment was evaluated to determine the extent of exposure to individuals at the control area boundary. Consequence assessments were performed on these chemical releases using the ALOHA model, vapor generation model, and a bounding spill depth calculation. The assumptions and methodology used in these assessments are identified in *Table 4-6* (Environmental Safety Chemical Assumptions for Scenario Development). The quantitative results of the chemical assessments were used to estimate the concentration ranges above which acute exposure would

be expected to lead to adverse health effects (ERPG and TEEL limits) at the control area boundary.

The risk associated with each intermediate and high consequence event related to the release of these chemicals was evaluated. The margin of safety necessary to reduce exposure to individuals at the control area boundary to below the ERPG and/or TEEL limits is provided by engineered controls, administrative controls, or both dependent upon the extent necessary. The following general controls have been identified for the storage of bulk chemicals:

- Materials of construction
- Dike containment
- Procedures and Training

The measures applied to a particular engineered or administrative control or control system will be commensurate with the risk reduction attributed to the control or control system.

Table 4-4
Environmental Chemical Safety Consequence Bounding Table

Scenario Number	Scenario Evaluated	Applies to	Bounding Volumes	High, Intermediate or Low Consequence
1	Spill of Nitric Acid (67%) [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	<10 gallons (39 liters)	Low
2	Spill of Nitric Acid (67%) [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	>10 gallons (39 liters) but less than or equal to 62 gallons (237 liters)	Intermediate
3	Spill of Nitric Acid (67%) [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	>62 gallons (237 liters)	High
4:1	Spill of Nitric Acid Solutions [indoors]	Bounds any nitric acid solution spilled inside Building 333 with vapor released through the air exhaust stack #703 (not flowing out of building [redacted] door threshold 0.0328)	7,928 gallons (30,010 liters) for Dissolution Area (inside MAA) 240 gallons (908 liters) for the Downblending Area 9,026 gallons (34,167 liters) for the SX Area not flowing outside	Low
5	Uranyl Nitrate [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	<41 gallons (155 liters)	Low
6	Uranyl Nitrate [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	>41 gallons (155 liters) but less than or equal to 250 gallons (946 liters)	Intermediate
7	Uranyl Nitrate [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	> 250 gallons (946 liters)	High
8:1	Overflow Uranyl Nitrate [outdoors]	One hour overflow assuming all of the spill is outside of Building [redacted] (175 ft from control area boundary)	203 gallons (770 liters) of 20% Nitric Acid solution diluted with 77 gallons (184 liters) DI water released outdoors	Low
9	Uranyl Nitrate [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	2,906 gallons (11,000 liters) or less of a 5% nitric acid solution	Low
10	Failure to add Hydrogen Peroxide (Nitric Oxide vapor release)	U-metal dissolution process: failure to add hydrogen peroxide with potential release of nitric oxide	Process Specific Scenario (Not evaluated as a bounding scenario)	Low

Scenario Number	Scenario Evaluated	Applies to	Bounding Volumes	High, Intermediate or Low Consequence
11.1	Hydrogen Peroxide Spill [indoors]	Hydrogen Peroxide spill in Building [redacted] (or [redacted] complex) of less than the identified amount with vapor released through the air exhaust stack #703 at 175 ft from control area boundary (No consideration taken for concentration)	163 gallons (617 liters) or less	Low
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic) , Sodium Carbonate Solution Spills [outdoors]	Spills of all sodium hydroxide (caustic) solutions	Not bounded	Low
13	Ammonia Vapor Release [outdoors]	Ammonia release from [redacted] complex process or spills of ammonia generating vapors released at ground level 175 feet from control area boundary.	21.7 lbs/hr or less	Low
14.1	Nitric Oxide Vapor Release [indoors]	Bounding any failure of Air Pollution Control equipment for 300 Complex and failures of process containment devices (WOG, POG, Glove Boxes, ect.) inside Building [redacted] (BPF) released NO_x through Room Air Vent Stack #704	≤1,025 lb/hr	Low
			≥1,025 lb/hr ≤3900	Intermediate
			≥3,900 lb/hr	High
15	Nitric Acid Solution [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	8,815 gallons (33,368 liters) or less of a nitric acid solution	Low
16	Nitric Acid Solution [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	greater than 8,815 gallons (33,368 liters) and less than or equal to 52,930 gallons (200,362 liters) of a nitric acid solution	Intermediate
17	Nitric Acid Solution [outdoors]	Outdoor Spill or spills potentially flowing out of a building 175 ft from the control area boundary	greater than 52,930 gallons (200,362 liters) of a nitric acid solution	High
18	Nitric Acid (67%) overflow with water [outdoors]	BPF Tray Dissolver Overflow	Process Specific Scenario (Not evaluated as a bounding scenario)	Low

Scenario Number	Scenario Evaluated	Applies to	Bounding Volumes	High, Intermediate or Low Consequence
19.1	Norpar-12 spill [outdoors]	Outdoor Spill or spills potentially flowing out of Building [redacted] 75 ft from the control area boundary	66,672 gallons (252,380 liters) or less of Norpar-12	Low
20.1	Trybutyl Phosphate (TBP) spill [indoors]	Outdoor Spill or spills potentially flowing out of Building [redacted] 75 ft from the control area boundary	4,362 gallons (16,511 liters) or less of 100% TBP 175 feet from the control area boundary	Low
21	Trybutyl Phosphate (TBP) Spill [outdoors Bulk Chemical Tank Farm]	Outdoor spill at Bulk Chemical Tank Farm, 100 % TBP 175 ft. from the control area boundary	<2,491 gallons (9,429 liters)	Low
22	Trybutyl Phosphate (TBP) Spill [outdoors Bulk Chemical Tank Farm]	Outdoor spill at Bulk Chemical Tank Farm, 100 % TBP 175 ft. from the control area boundary	> 2,491 gallons (9,429 liters), but less than 4,163 gallons (15,759 liters)	Intermediate
23	Trybutyl Phosphate (TBP) Spill [outdoors Bulk Chemical Tank Farm]	Outdoor spill at Bulk Chemical Tank Farm, 100 % TBP 175 ft. from the control area boundary	> 4,163 gallons (15,759 liters)	High
24	Hydrogen Peroxide (H_2O_2) Spill [outdoors Bulk Chemical Tank Farm)	Outdoor spill at Bulk Chemical Tank Farm, 175 ft. from the control area boundary	<278 gallons (1,052 liters)	Low
25	Hydrogen Peroxide (H_2O_2) Spill [outdoors Bulk Chemical Tank Farm)	Outdoor spill at Bulk Chemical Tank Farm, 175 ft. from the control area boundary	> 278 gallons (1,052 liters), but less than 3,483 gallons (13,184 liters)	Intermediate
26	Hydrogen Peroxide (H_2O_2) Spill [outdoors Bulk Chemical Tank Farm)	Outdoor spill at Bulk Chemical Tank Farm, 175 ft. from the control area boundary	>3,483 gallons (13,184 liters)	High
27.1	UAI glovebox enclosure explosion	Environmental safety chemical consequences of a BPF specific explosion scenario evaluated by Fire Protection Safety	Process specific scenario	High
28.1	UAI failure to purge explosion	Environmental safety chemical consequences of a BPF specific explosion scenario evaluated by Fire Protection Safety	Process specific scenario	Low
29.1	DI water overflow of tank in Downblending Area [outdoors]	BPF process specific scenario for Downblending Area of Building [redacted]	Process specific scenario	High
30	Cooling Water Tower[40% Propylene Glycol/60% Water]	BPF Process	Not Bounding	Low

Scenario Number	Scenario Evaluated	Applies to	Bounding Volumes	High, Intermediate or Low Consequence
31	Cooling Water Tower [NT 411 & Water]	BPF Process	Not Bounding	N/A
32 I	DI Water Overflow of Sparging Station [outdoors]	BPF Natural Dissolution Area	Not Bounding	N/A
33	Incompatible Materials from outside LEU Downblending LEU	BPF Natural Dissolution Area	Not Bounding	N/A
34	Sodium Hydroxide 30% [outdoor]	Potential release & overflow of NaOH to a waste discard tank at WWTF	Not Bounding	Low
35	Spill of Sodium Nitrate [outdoor]	Spill of Sodium Nitrate in tanker from caustic make-up and storage tanks	Evaluated at 1600 gallons, stays intermediate for entire tanker of 2100 gallons - Bounding	Intermediate

Table 4-5
Environmental Chemical Safety Consequence Analysis Summary

(Note: Refer to the previous table for details on each evaluation number)

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		U Metal Dissolution (Baseline)	
4.1	Spill of Nitric Acid Solutions [Indoors]	1UMD (1.1, 1.4, 1.7, 1.8, 1.13, 1.14, 1.17, 1.18, 1.19, 1.44, 1.47, 1.53, 1.56, 1.59, 1.79, 1.80, 1.82, 1.86, 1.87, 1.106, 1.107, 1.109, 1.124, 1.128, 1.136, 1.139, 1.141, 1.147, 1.148, 1.150, 1.152, 1.154, 1.156, 1.158, 1.162, 1.182) 2UMD (2.1, 2.4, 2.7, 2.8, 2.13, 2.14, 2.17, 2.18, 2.19, 2.44, 2.47, 2.53, 2.56, 2.59, 2.79, 2.80, 2.82, 2.86, 2.87, 2.106, 2.107, 2.109, 2.124, 2.128, 2.136, 2.139, 2.141, 2.147, 2.148, 2.150, 2.152, 2.154, 2.156, 2.158, 2.162, 2.182) 3DT (3.1, 3.2, 3.3, 3.10, 3.11, 3.13, 3.14, 3.18, 3.19, 3.20, 3.21, 3.23, 3.24, 3.25, 3.33, 3.36, 3.37, 3.49, 3.50, 3.52, 3.59) 7DT (4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.14, 4.16, 4.17, 4.19, 4.20, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33, 4.35, 4.36, 4.37, 4.41, 4.45, 4.47, 4.48, 4.53)	Low
10	Failure to add Hydrogen Peroxide	1UMD (1.37, 1.39, 1.41, 1.46, 1.146) 2UMD (2.37, 2.39, 2.41, 2.46, 2.146)	Low
11.1	Spill of Hydrogen Peroxide [Outdoors]	1UMD (1.23, 1.26, 1.27, 1.30, 1.31, 1.34, 1.35, 1.36, 1.143, 1.145) 2UMD (2.23, 2.26, 2.27, 2.30, 2.31, 2.34, 2.35, 2.36, 2.143, 2.145)	Low
		U-Al Dissolution (Baseline)	
4.1	Spill of Nitric Acid Solutions [Indoors]	1UALS (33.10, 33.14, 33.16, 33.19, 33.21, 33.29, 33.54, 33.55, 33.60, 33.61, 33.62, 33.64, 33.66, 33.69, 33.71, 33.74, 33.75, 33.77, 33.87, 33.89, 33.90, 33.95, 33.98, 33.107, 33.108, 33.109, 33.111) 2UALS (34.10, 34.14, 34.16, 34.19, 34.21, 34.29, 34.52, 34.53, 34.54, 34.55, 34.57, 34.59, 34.62, 34.64, 34.67, 34.68, 34.70, 34.80, 34.82, 34.83, 34.88, 34.90, 34.91, 34.93, 34.105, 34.106, 34.107, 34.109) UALAC (37.3, 37.5, 37.6, 37.9, 37.10, 37.11, 37.13, 37.16, 37.17, 37.18, 37.28, 37.29, 37.38, 37.39, 37.42, 37.46)	Low
8.1	Overflow Uranyl Nitrate (Nitric Acid) [Outdoors]	1UALS (33.10, 33.14, 33.16, 33.19, 33.21, 33.29) 2UALS (34.10, 34.14, 34.16, 34.19, 34.21, 34.29, 34.55) UALAC (37.3)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic) Spill [Outdoors]	1UALD (29.16, 29.20, 29.22, 29.23, 29.25, 29.26, 29.27, 29.30, 29.31, 29.33, 29.35, 29.45, 29.48, 29.49, 29.60, 29.63, 29.64, 29.66, 29.68, 29.70, 29.76, 29.77, 29.78, 29.80, 29.84, 29.88, 29.89, 29.91) 2UALD (30.16, 30.20, 30.22, 30.23, 30.25, 30.26, 30.27, 30.30, 30.31, 30.33, 30.35, 30.45, 30.48, 30.49, 30.60, 30.63, 30.64, 30.66, 30.68, 30.70, 30.76, 30.77, 30.78, 30.80, 30.84, 30.88, 30.89, 30.91) 3UALD (31.16, 31.20, 31.22, 31.23, 31.25, 31.26, 31.27, 31.30, 31.31, 31.33, 31.35, 31.45, 31.48, 31.49, 31.60, 31.63, 31.64, 31.66, 31.68, 30.70, 31.76, 31.77, 31.78, 31.80, 31.84, 31.88, 31.89, 31.91) 4UALD (32.16, 32.20, 32.22, 32.23, 32.25, 32.26, 32.27, 32.30, 32.31, 32.33, 32.35, 32.45, 32.48, 32.49, 32.60, 32.63, 32.64, 32.66, 32.68, 32.70, 32.76, 32.77, 32.78, 32.80, 32.84, 32.88, 32.89, 32.91) 1UALS (33.24, 33.27, 33.28, 33.33, 33.34, 33.35, 33.36, 33.37, 33.39, 33.40, 33.41, 33.42, 33.43, 33.45, 33.46, 33.47, 33.48, 33.49, 33.50, 33.51) 2UALS (34.24, 34.27, 34.28, 34.33, 34.34, 34.35, 34.36, 34.37, 34.39, 34.40, 34.41, 34.42, 34.43, 34.45, 34.46, 34.47, 34.48, 34.49, 34.50, 34.51) 1UALC (35.3, 35.7, 35.8, 35.9, 35.12, 35.13, 35.14, 35.16, 35.19, 35.20, 35.21, 35.25, 35.34, 35.36, 35.40, 35.41, 35.42, 35.44, 35.48, 35.51, 35.59) 2UALC (36.3, 36.7, 36.8, 36.9, 36.12, 36.13, 36.14, 36.16, 36.17, 36.19, 36.20, 36.21, 36.25, 36.34, 36.36, 36.40, 36.41, 36.42, 36.48, 36.51, 36.59) GMST (38.1, 38.3, 38.5, 38.6, 38.7, 38.8, 38.9, 38.14, 38.15, 38.16, 38.17, 38.18, 38.19, 38.20, 38.24, 38.25, 38.26, 38.28, 38.30, 38.31, 38.32, 38.33, 38.34, 38.36, 38.39, 38.42, 38.44, 38.46, 38.47, 38.48, 38.50, 38.51)	Low
13	Ammonia Vapor Release [outdoors]	1UALD (29.63, 29.64, 29.66, 29.68, 29.70, 29.84, 29.88) 2UALD (30.63, 30.64, 30.66, 30.68, 30.70, 30.84, 30.88) 3UALD (31.63, 31.64, 31.66, 31.68, 31.70, 31.84, 31.88) 4UALD (32.63, 32.64, 32.66, 32.68, 32.70, 32.84, 32.88)	Low
14.1	Nitric Oxide Vapor Release	1UALS (33.1, 33.3, 33.5, 33.7, 33.12, 33.13, 33.14, 33.104) 2UALS (34.1, 34.3, 34.5, 34.7, 34.12, 34.13, 34.14, 34.102)	Low
27.1	UAI Glovebox Enclosure Explosion	1UALD (29.45, 29.48, 29.49, 29.66, 29.70, 29.84) 2UALD (30.45, 30.48, 30.49, 30.66, 30.70, 30.84) 3UALD (31.45, 31.48, 31.49, 31.66, 31.70, 31.84) 4UALD (32.45, 32.48, 32.49, 32.66, 32.70, 32.84)	High

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
28.1	UAl failure to purge explosion	1UALD (29.23, 29.25, 29.26, 29.30, 29.33, 29.78, 29.76, 29.80) 2UALD (30.23, 30.25, 30.26, 30.30, 30.33, 30.76, 30.78, 30.80) 3UALD (31.23, 31.25, 31.26, 31.30, 31.33, 31.76, 31.78, 31.80) 4UALD (32.23, 32.25, 32.26, 32.30, 32.33, 32.76, 32.78, 32.80)	Low
35	Caustic Tanker breach	CMST(38.52)	Intermediate
		BPF Solvent Extraction Staging Columns (Baseline)	
4.1	Spill of Nitric Acid Solutions [Indoors]	SXFC (9.3, 9.5, 9.13, 9.14, 9.15, 9.21, 9.22, 9.25, 9.27, 9.28, 9.30, 9.31, 9.34, 9.37, 9.38, 9.44, 9.45, 9.46, 9.47, 9.50, 9.52, 9.53, 9.60, 9.62, 9.64, 9.65)	Low
8.1	Overflow Uranyl Nitrate (Nitric Acid) [Outdoors]	SXFC (9.9, 9.11)	Low
14.1	Nitric Oxide Vapor Release	SXFC (9.38)	Low
		BPF First Pass Solvent Extraction (Baseline)	
4.1	Spill of Nitric Acid Solutions [Indoors]	1PX (10.1, 10.2, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.56, 10.57, 10.58, 10.59, 10.60, 10.61, 10.62, 10.63, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.74, 10.75, 10.76, 10.77, 10.78, 10.80, 10.81, 10.82, 10.83, 10.84, 10.85, 10.86, 10.88, 10.89, 10.90, 10.91, 10.92, 10.94, 10.95, 10.96, 10.97, 10.98, 10.99, 10.100, 10.103, 10.104, 10.105, 10.106, 10.107, 10.108, 10.109, 10.110, 10.112, 10.119, 10.122, 10.124, 10.126)	Low
14.1	Nitric Oxide Vapor Release	1PX (10.129)	Low
19.1	Norpar Spill	1PX (10.2, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.56, 10.57, 10.58, 10.59, 10.60, 10.61, 10.62, 10.63, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.74, 10.75, 10.76, 10.77, 10.78, 10.80, 10.81, 10.82, 10.83, 10.84, 10.85, 10.86, 10.88, 10.89, 10.90, 10.91, 10.92, 10.94, 10.95, 10.96, 10.97, 10.98, 10.99, 10.100, 10.103, 10.104, 10.105, 10.106, 10.107, 10.108, 10.109, 10.110, 10.112, 10.116, 10.119, 10.122, 10.124, 10.126)	Low
20.1	Tributyl Phophate (TBP) Spill [indoors]	1PX (10.2, 10.3, 10.5, 10.6, 10.7, 10.9, 10.11, 10.13, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.55, 10.56, 10.57, 10.58, 10.59, 10.60, 10.61, 10.62, 10.63, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.74, 10.75, 10.76, 10.77, 10.78, 10.80, 10.81, 10.82, 10.83, 10.84, 10.85, 10.86, 10.88, 10.89, 10.90, 10.91, 10.92, 10.94, 10.95, 10.96, 10.97, 10.98, 10.99, 10.100, 10.103, 10.104, 10.105, 10.106, 10.107, 10.108, 10.109, 10.110, 10.112, 10.119, 10.122, 10.124, 10.126)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		BPF First Pass Evaporator (Baseline)	
4.1	Spill of Nitric Acid Solutions [Indoors]	1PE (12.24, 12.28, 12.26, 12.30, 12.32, 12.34, 12.43, 12.45, 12.47, 12.52, 12.55, 12.56, 12.59, 12.60, 12.61, 12.62, 12.63, 12.64, 12.65, 12.66, 12.67, 12.68, 12.69, 12.70, 12.72, 12.73, 12.74, 12.75, 12.79, 12.80, 12.81, 12.82, 12.83, 12.88, 12.90, 12.92, 12.95, 12.100, 12.102, 12.103, 12.106, 12.107, 12.108, 12.110, 12.113, 12.114, 12.115, 12.116, 12.117, 12.118, 12.120, 12.121, 12.122, 12.128, 12.130, 12.167, 12.179, 12.185, 12.186, 12.187)	Low
14.1	Nitric Oxide Vapor Release	1PE (12.26, 12.28, 12.85, 12.89, 12.91, 12.94, 12.99, 12.132)	Low
		BPF Second Pass Solvent Extraction (Baseline)	
4.1	Spill of Nitric Acid Solutions [Indoors]	2PSX (13.1, 13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.35, 13.36, 13.37, 13.38, 13.39, 13.40, 13.41, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.50, 13.51, 13.52, 13.53, 13.54, 13.56, 13.57, 13.58, 13.59, 13.60, 13.62, 13.63, 13.64, 13.65, 13.66, 13.67, 13.68, 13.69, 13.70, 13.71, 13.75, 13.77, 13.82, 13.84, 13.89, 13.90, 13.91, 13.93)	Low
14.1	Nitric Oxide Vapor Release	2PSX (13.86)	Low
19.1	Norpar Spill	2PSX (13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.35, 13.36, 13.37, 13.38, 13.39, 13.40, 13.41, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.50, 13.51, 13.52, 13.53, 13.54, 13.56, 13.57, 13.58, 13.59, 13.60, 13.62, 13.63, 13.64, 13.65, 13.66, 13.67, 13.68, 13.69, 13.70, 13.71, 13.75, 13.77, 13.80, 13.82, 13.84, 13.89, 13.90, 13.91, 13.93)	Low
20.1	TBP spill	2PSX (13.2, 13.3, 13.5, 13.7, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.35, 13.36, 13.37, 13.38, 13.39, 13.40, 13.41, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.50, 13.51, 13.52, 13.53, 13.54, 13.56, 13.57, 13.58, 13.59, 13.60, 13.62, 13.63, 13.64, 13.65, 13.66, 13.67, 13.68, 13.69, 13.70, 13.71, 13.75, 13.77, 13.80, 13.82, 13.84, 13.89, 13.90, 13.91, 13.93)	Low
		BPF Second Pass Solvent Wash (Baseline)	
4.1	Spill of Nitric Acid Solutions [Indoors]	2PSW (14.1, 14.6, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.25, 14.26, 14.27, 14.28, 14.30, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.57, 14.58, 14.59, 14.60, 14.61, 14.62, 14.63, 14.65, 14.67, 14.68, 14.69, 14.70, 14.71, 14.73, 14.74, 14.75, 14.77, 14.78, 14.79, 14.80, 14.82, 14.83, 14.84, 14.85, 14.90, 14.91, 14.92, 14.93, 14.94, 14.95, 14.99, 14.101, 14.102, 14.103, 14.106, 14.108, 14.110, 14.111)	Low
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic), Sodium Carbonate 5% Solution Spills [Outdoors]	2PSW (14.8)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
14.1	Nitric Oxide Vapor Release	2PSW (14.116)	Low
19.1	Norpar Spill	2PSW (14.1, 14.2, 14.3, 14.6, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.25, 14.26, 14.27, 14.28, 14.30, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.57, 14.58, 14.59, 14.60, 14.61, 14.62, 14.63, 14.65, 14.67, 14.68, 14.69, 14.70, 14.71, 14.73, 14.74, 14.75, 14.77, 14.78, 14.79, 14.80, 14.82, 14.83, 14.84, 14.85, 14.90, 14.91, 14.92, 14.93, 14.94, 14.95, 14.99, 14.101, 14.102, 14.103, 14.106, 14.108, 14.110, 14.111)	Low
20.1	TBP spill	2PSW (14.1, 14.2, 14.3, 14.6, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.25, 14.26, 14.27, 14.28, 14.30, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.57, 14.58, 14.59, 14.60, 14.61, 14.62, 14.63, 14.65, 14.67, 14.68, 14.69, 14.70, 14.71, 14.73, 14.74, 14.75, 14.77, 14.78, 14.79, 14.80, 14.82, 14.83, 14.84, 14.85, 14.90, 14.91, 14.92, 14.93, 14.94, 14.95, 14.99, 14.101, 14.102, 14.103, 14.106, 14.108, 14.110, 14.111)	Low
BPF Second Pass Evaporator (Baseline)			
4.1	Spill of Nitric Acid Solutions [Indoors]	2PE (15.24, 15.26, 15.28, 15.30, 15.32, 15.34, 15.47, 15.50, 15.51, 15.54, 15.55, 15.56, 15.57, 15.58, 15.59, 15.60, 15.61, 15.62, 15.63, 15.64, 15.66, 15.67, 15.68, 15.69, 15.73, 15.74, 15.75, 15.76, 15.77, 15.82, 15.84, 15.86, 15.89, 15.92, 15.94, 15.95, 15.96, 15.98, 15.99, 15.100, 15.102, 15.104, 15.141, 15.153, 15.155, 15.156, 15.157)	Low
14.1	Nitric Oxide Vapor Release	2PE (15.28, 15.79, 15.83, 15.85, 15.91, 15.106)	Low
BPF Solvent Extraction Interface Solids Filtering (Baseline)			
4.1	Spill of Nitric Acid Solutions [Indoors]	SXSF (16.1, 16.9, 16.15, 16.16, 16.19, 16.31, 16.37, 16.39, 16.40, 16.41, 16.44, 16.45, 16.52, 16.55, 16.57, 16.59)	Low
14.1	Nitric Oxide Vapor Release	SXSF (16.14, 16.27, 16.28, 16.29, 16.31)	Low
BPF First Pass Raffinate Storage (Baseline)			
4.1	Spill of Nitric Acid Solutions [Indoors]	1PRS (17.3, 17.5, 17.9, 17.11, 17.14, 17.15, 17.18, 17.19, 17.21, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.32, 17.33, 17.34, 17.45, 17.47, 17.51, 17.57, 17.61, 17.65, 17.76, 17.77, 17.79, 17.82, 17.83, 17.85)	Low
14.1	Nitric Oxide Vapor Release	1PRS (17.61, 17.62)	Low
19.1	Norpar Spill	1PRS (17.3, 17.5, 17.9, 17.11, 17.19, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.32, 17.33, 17.34, 17.45, 17.47, 17.51, 17.57, 17.61, 17.65, 17.76, 17.77, 17.79, 17.82, 17.83, 17.85)	Low
20.1	TBP spill	1PRS (17.3, 17.5, 17.9, 17.11, 17.19, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.32, 17.33, 17.34, 17.45, 17.47, 17.51, 17.57, 17.61, 17.65, 17.76, 17.77, 17.79, 17.82, 17.83, 17.85)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		BPF Second Pass Raffinate Storage (Baseline)	
4:1	Spill of Nitric Acid Solutions [Indoors]	2PRS (18.2, 18.8, 18.9, 18.11, 18.12, 18.14, 18.16, 18.17, 18.18, 18.19, 18.22, 18.26, 18.29, 18.30, 18.33, 18.34, 18.35)	Low
14:1	Nitric Oxide Vapor Release	2PRS (18.26, 18.27)	Low
19:1	Norpar-12 spill	2PRS (18.2, 18.9, 18.11, 18.12, 18.14, 18.16, 18.17, 18.18, 18.19, 18.22, 18.29, 18.30, 18.33, 18.34, 18.35)	Low
20:1	TBP spill	2PRS (18.2, 18.9, 18.11, 18.12, 18.14, 18.16, 18.17, 18.18, 18.19, 18.22, 18.29, 18.30, 18.33, 18.34, 18.35)	Low
		BPF Solvent Extraction Sump Columns (Baseline)	
4:1	Spill of Nitric Acid Solutions [Indoors]	SXSC (19.5, 19.8, 19.9, 19.11, 19.12, 19.14, 19.15, 19.20, 19.22)	Low
14:1	Nitric Oxide Vapor Release	SXSC (19.22, 19.23)	Low
19:1	Norpar Spill	SXSC (19.5, 19.9, 19.11, 19.12, 19.14, 19.15, 19.20)	Low
20:1	TBP spill	SXSC (19.5, 19.9, 19.11, 19.12, 19.14, 19.15, 19.20)	Low
		BPF Evaporator Condensate Columns Set A (Baseline)	
4:1	Spill of Nitric Acid Solutions [Indoors]	ECA (20.2, 20.4, 20.5, 20.7, 20.8, 20.10, 20.11, 20.17, 20.31, 20.40, 20.41, 20.43)	Low
14:1	Nitric Oxide Vapor Release	ECA (20.31, 20.32)	Low
19:1	Norpar Spill	ECA (20.17)	Low
20:1	TBP spill	ECA (20.17)	Low
		BPF Evaporator Condensate Columns Set B (Baseline)	
4:1	Spill of Nitric Acid Solutions [Indoors]	ECB (21.1, 21.3, 21.4, 21.6, 21.7, 21.13, 21.27, 21.36, 21.37, 21.39)	Low
14:1	Nitric Oxide Vapor Release	ECB (21.27, 21.28)	Low
19:1	Norpar-12 spill	ECB (21.13)	Low
20:1	TBP spill	ECB (21.13)	Low
		BPF Solvent Extraction Product Storage Columns (Baseline)	
4:1	Spill of Nitric Acid Solutions [Indoors]	SXPS (22.3, 22.5, 22.26, 22.28, 22.30, 22.32, 22.34, 22.36, 22.38, 22.40, 22.41, 22.43, 22.45, 22.46, 22.47, 22.48, 22.49, 22.50, 22.51, 22.52, 22.53, 22.55, 22.59, 22.61, 22.63, 22.67, 22.70, 22.72, 22.74, 22.76)	Low
14:1	Nitric Oxide Vapor Release	SXPS (22.34, 22.35)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
BPF Solvent Extraction Chemical Makeup Area (Baseline)			
4.1	Spill of Nitric Acid Solutions [Indoors]	1SXCM (23.4, 23.6, 23.55, 23.67, 23.69, 23.70, 23.71, 23.72, 23.79, 23.86)	Low
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic), Sodium Carbonate Solution Spills [Outdoors]	1SXCM (23.1, 23.44, 23.48, 23.51, 23.53, 23.54, 23.58, 23.61, 23.62, 23.82, 23.86, 23.88)	Low
14.1	Nitric Oxide Vapor Release	1SXCM (23.80, 23.85, 23.87)	Low
19.1	Norpar-12 spill	1SXCM (23.7, 23.8, 23.9, 23.10, 23.12, 23.13, 23.18, 23.19, 23.20, 23.22, 23.24, 23.26, 23.27, 23.34, 23.36, 23.37, 23.38, 23.39, 23.40, 23.41, 23.42, 23.55, 23.82, 23.86)	Low
20.1	TBP spill	1SXCM (23.7, 23.8, 23.24, 23.26, 23.27, 23.29, 23.34, 23.36, 23.37, 23.38, 23.39, 23.40, 23.41, 23.42, 23.55, 23.82, 23.86)	Low
BPF Solvent Extraction Chemical Makeup Area (Sheet 2) (Baseline)			
4.1	Spill of Nitric Acid Solutions [Indoors]	2SXCM (24.2, 24.7, 24.8, 24.10, 24.14, 24.16, 24.18, 24.20, 24.22, 24.27, 24.28, 24.29, 24.32, 24.38, 24.52)	Low
8	Overflow Uranyl Nitrate (Nitric Acid) [Outdoors]	2SXCM (24.1, 24.52)	Low
14.1	Nitric Oxide Vapor Release	2SXCM (24.50, 24.53, 24.54)	Low
19.1	Norpar-12 spill	2SXCM (24.16, 24.18, 24.20, 24.22)	Low
20.1	TBP spill	2SXCM (24.16, 24.18, 24.20, 24.22)	Low
BPF Ventilation Knockout Columns (Baseline)			
4.1	Spill of Nitric Acid Solutions [Indoors]	VKC (25.3, 25.5, 25.6)	Low
19.1	Norpar-12 spill	VKC (25.3, 25.5, 25.6)	Low
20.1	TBP spill	VKC (25.3, 25.5, 25.6)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		BPF First Pass Solvent Wash (Baseline)	
4:1	Spill of Nitric Acid Solutions [Indoors]	1PSW (11:1, 11:6, 11:10, 11:11, 11:12, 11:13, 11:14, 11:22, 11:24, 11:25, 11:26, 11:27, 11:28, 11:30, 11:40, 11:41, 11:48, 11:49, 11:50, 11:51, 11:52, 11:53, 11:54, 11:55, 11:56, 11:57, 11:58, 11:59, 11:60, 11:61, 11:62, 11:63, 11:65, 11:67, 11:68, 11:69, 11:70, 11:71, 11:73, 11:74, 11:75, 11:77, 11:78, 11:79, 11:80, 11:82, 11:83, 11:84, 11:85, 11:90, 11:91, 11:92, 11:93, 11:94, 11:95, 11:99, 11:101, 11:102, 11:103, 11:106, 11:107, 11:112, 11:114, 11:116)	Low
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic), Sodium Carbonate Solution Spills [Outdoors]	1PSW (11.8)	Low
14:1	Nitric Oxide Vapor Release	1PSW (11.116)	Low
19:1	Norpar-12 spill	1PSW (11:2, 11:3, 11:6, 11:10, 11:11, 11:12, 11:13, 11:14, 11:22, 11:24, 11:27, 11:28, 11:30, 11:40, 11:41, 11:48, 11:49, 11:50, 11:51, 11:52, 11:53, 11:54, 11:55, 11:56, 11:57, 11:58, 11:59, 11:60, 11:61, 11:62, 11:63, 11:65, 11:67, 11:68, 11:69, 11:70, 11:71, 11:73, 11:74, 11:75, 11:77, 11:78, 11:79, 11:80, 11:82, 11:83, 11:84, 11:85, 11:90, 11:91, 11:92, 11:93, 11:94, 11:95, 11:99, 11:101, 11:102, 11:103, 11:106, 11:107, 11:112, 11:114, 11:116)	Low
		BPF Downblending	
3	Spill of 67% Nitric Acid [Outdoors]	UND (6.39, 6.43)	High
4:1	Spill of Nitric Acid Solutions [Indoors]	UND (6.41, 6.59, 6.60, 6.62, 6.63, 6.66, 6.69, 6.71, 6.72, 6.80, 6.81, 6.84, 6.100, 6.101, 6.102, 6.104, 6.176, 6.177, 6.179, 6.184, 6.186, 6.188, 6.190, 6.193, 6.196, 6.199, 6.2116.212, 6.221, 6.225, 6.227, 6.228, 6.235, 6.236, 6.237, 6.238, 6.241, 6.242, 6.243) UMM (8.1, 8.3, 8.5, 8.10, 8.12, 8.15, 8.16, 8.17, 8.19, 8.20, 8.22, 8.23, 8.26, 8.32) UDB (5.3, 5.5, 5.13, 5.14, 5.34, 5.44, 5.46, 5.54, 5.55, 5.57) UNT (7.68)	Low
8:1	Overflow Uranyl Nitrate (Nitric Acid) [Outdoors]	UDB (5.8, 5.13, 5.14, 5.16, 5.18, 5.20, 5.22, 5.24, 5.26, 5.28, 5.30, 5.32)	Low
14:1	Nitric Oxide Vapor Release	UND (6.68, 6.110, 6.158, 6.165, 6.172, 6.173, 6.187, 6.193, 6.196, 6.225, 6.224, 6.226, 6.233, 6.246) UDB (5.138, 5.139, 5.140, 5.141, 5.142, 5.143, 5.147) UNT (7.23, 7.24, 7.53, 7.54, 7.55, 7.56)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
15	Spill of Nitric Acid Solution [outdoor]	UDB (5.52, 5.78, 5.80, 5.83, 5.84, 5.88, 5.91, 5.93, 5.94, 5.97, 5.100, 5.101, 5.103, 5.116, 5.120, 5.122, 5.126, 5.128, 5.129, 5.132, 5.138, 5.140, 5.144, 5.145, 5.146, 5.150) UND (6.261, 6.266, 6.268, 6.272, 6.281) UNT (7.3, 7.5, 7.8, 7.12, 7.13, 7.17, 7.19, 7.20, 7.22, 7.25, 7.31, 7.35, 7.37, 7.38, 7.39, 7.41, 7.42, 7.43, 7.44, 7.45, 7.46, 7.47, 7.50, 7.51, 7.53, 7.65)	Low
29.1	DI water overflow of tank in Downblending Area [outdoors]	UND (6.46)	High
33	Incompatible Materials from Outside LEU Downblending	UND (6.283)	N/A
		Liquid Discards (Baseline)	
9	Uranyl Nitrate (5%) Nitric Acid [Outdoors]	ND (26.1, 26.2, 26.4, 26.12, 26.16, 26.17, 26.18, 26.21, 26.23, 26.24, 26.27, 26.31, 26.32, 26.37, 26.39, 26.41, 26.42, 26.43, 26.46)	Low
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic) Spill [Outdoors]	CD (27.1, 27.2, 27.4, 27.12, 27.21, 27.24, 27.26, 27.27, 27.31, 27.32, 27.37, 27.39, 27.41, 27.42, 27.43, 27.54)	Low
14.1	Nitric Oxide Vapor Release	ND (26.26, 26.50, 26.51) CD (27.48, 27.49)	Low
		BPF Ventilation (Baseline)	
Note: No Environmental Non-Radiological issues were identified for the Radiological Air Sampler and Vacuum Pumps ISA Baseline table (RAS) issued on 3/25/02.			
4.1	Spill of Nitric Acid Solution [indoors]	PS (45.118)	High
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic) Spill [Outdoors]	PS (45.4, 45.5, 45.7, 45.11, 45.13, 45.17, 45.19, 45.21, 45.25, 45.33, 45.46, 45.60, 45.64, 45.66, 45.70, 45.75, 45.78, 45.79, 45.80, 45.81, 45.83, 45.84, 45.87, 45.89, 45.91, 45.92, 45.95, 45.96, 45.101, 45.106, 45.107, 45.112, 45.120, 45.126, 45.132, 45.134, 45.136, 45.138) PV (44.14)	Low
14.1	Nitric Oxide Vapor Release	PS (45.2, 45.3, 45.7, 45.10, 45.11, 45.12, 45.13, 45.14, 45.19, 45.22, 45.24, 45.26, 45.28, 45.29, 45.31, 45.34, 45.38, 45.40, 45.41, 45.52, 45.67, 45.109, 45.111, 45.112, 45.120, 45.127, 45.131, 45.136, 45.138, 45.142, 45.143, 45.144) PV (44.1, 44.3, 44.5, 44.7, 44.9, 44.11, 44.17, 44.18, 44.20, 44.21, 44.22, 44.23, 44.24)	Low
34	Sodium Hydroxide spill or release to waste discard tank at WWTF [outdoors]	PS (45.88, 45.140, 45.141)	Low
		Utilities (Baseline)	
3	Spill of Nitric Acid (67%) [outdoors]	UTD (40.17)	High

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
11.1	Hydrogen Peroxide Spill [Outdoors]	UTD (40.41)	Low
14.1	Nitric Oxide Vapor Release	UTD (40.1, 40.2, 40.4, 40.49, 40.50, 40.52, 40.56)	Low
NOTE: Item Numbers 40.1 & 40.2 were evaluated for use of NT 41.1 in Bldg. 333 Cooling Tower solution. No potential health consequence were identified at the control area boundary from an air emission release. However, a liquid release into the NFS storm water drainage system could cause a violation of the NPDES Storm Water Permit.			
		BPF External Events	
3	Spill of Nitric Acid (67%) [outdoors]	XE(46.7)	High
12	Sodium Hydroxide, Sodium Nitrate, Barium Nitrate Solution (Caustic) Spill [Outdoors]	XE(46.7)	Low
19.1	Norpar-12 spill	XE(46.7)	Low
21	Tributyl Phosphate (TBP) spill [outdoors Bulk Chemical Tank Farm]	XE(46.7)	Low
22	Hydrogen Peroxide Spill [outdoors Bulk Chemical Tank Farm]	XE(46.7)	Intermediate

Table 4-6
Environmental Safety Chemical Assumptions for Scenario Development

Parameter	Input Value	Units		Notes and Assumptions
Conversion Constants				
Weight of Water	8.34	lbs/gallon		
Gallons/ft^3	7.48	gal/ft^3		
Temperature				Or use a higher temperature value as appropriate (i.e., a reaction temperature of 90°C).
Max Bulk Chemical Temp	86	F	30.0C	
Max. Outdoor Temp.	95	F	35.0C	
Indoor Temp. (controlled env.)	70	F	21.1C	
Wind				
Outdoor Wind Speed	2.50	mph		Consistent with 1 m/s at 2 meters used by HP and 2.5 mph used by IS
Height of Measurement (outdoor wind)	10.00	meters		
Indoor Wind Speed	0.50	mph		Consistent with 0.5 mph used by IS
Height of Measurement (indoor wind)	*	meters		*Not a factor when using the Vapor Model
Stability Class	*			*Default value chosen by ALOHA Model (D used for outside spills)
Note: The Min. wind speed accepted by ALOHA is 1 m/s at 10 meters high				
Distance to nearest Controlled Area Boundary (outside controlled)				
From west side of Building 333	175	Ft		West to Protected Area Fence
From Main Stack #416	500	Ft		West to Protected Area Fence
From Building 333 air exhaust stack #703	175	Ft		West to Protected Area Fence
From Building 333 Hydrogen vent stack #704	175	ft		West to Protected Area Fence
From Bulk Chemical Tank Farm	175	ft		East to Protected Area Fence
Stack Information				
Air Exhaust Stack (#703)				
Stack Temperature	78.0	F	25.6C	Supporting documentation for Air Permit Application
Stack Height	58.25	ft	17.75m	Supporting documentation for Air Permit Application
Stack Diameter	2.80	ft	0.853m	Supporting documentation for Air Permit Application
Stack Exit Velocity	1,824.00	ft/min	20.7mph	Supporting documentation for Air Permit Application
Distance to Nearest Property Line	175.00	ft		Stack is located at the West end of Building 333

Parameter	Input Value	Units		Notes and Assumptions
Main Stack (#416)				
Stack Temperature	80	F	26.7C	Supporting documentation for Air Permit Application
Stack Height	108	ft	33m	Supporting documentation for Air Permit Application
Stack Diameter	5	ft	1.5m	Supporting documentation for Air Permit Application
Stack Exit Velocity	2,850.00	ft/min	32.4mph	Supporting documentation for Air Permit Application
Distance to Nearest Property Line	500	ft		
Hydrogen Vent (#704)				
Stack Temperature	65.0	F	18.3C	Supporting documentation for Air Permit Application
Stack Height	46.5	ft	14.2m	Supporting documentation for Air Permit Application
Stack Diameter	1.14	ft	0..35m	Supporting documentation for Air Permit Application
Stack Exit Velocity	1,974.00	ft/min	22.4mph	Supporting documentation for Air Permit Application
Distance to Nearest Property Line	175	ft		Assume stack is located at the West end of Building 333
Bldg. [redacted] Estimated Volume				e-mail from G.G. Pashal 4/29/02
Downblending	981.00	ft^2		
Dissolution	3,181.00	ft^2		
Solvent Extraction	4,477.00	ft^2		A spill in the solvent extraction area will spread into the dissolution area, thus providing a total containment area of 3,181 ft^2 + 4,477ft^2 = 7,658 ft^2.
Nitric Acid Vapor Pressure Table				Derived by K.D. Thompson, dated 5/29/02 from published data in Perry's Chemical Engineering Handbook
Material Safety Data Sheets				Nitric Acid, Trybutyl Phosphate (TBP), Ammonia, Sodium Hydroxide, Sodium Nitrate, Barium Nitrate, Sodium Carbonate, Hydrogen Peroxide, Norpar-12, and Uranyl Nitrate

Parameter	Input Value	Units	Notes and Assumptions
Exposure Guidelines ERPG			Emergency Response Planning Guidelines (ERPG), published by the American Industrial Hygiene Association (AIHA) as estimates of concentration ranges above which acute exposure would be expected to lead to adverse health effects (ERPG-1 &ERPG-2). ERPG-1 & ERPG-2 action levels are applicable to persons outside the control area boundary.
TEEL			Temporary Emergency Exposure Limits (TEELs), published by the DOE Emergency Management Advisory Committee's Subcommittee on Consequence Assessment and Protective Action (SCAPA). TEEL-1 and TEEL-2 are action limits applicable to persons outside the control area boundary when ERPG values are not defined.
ALOHA Model			Area Location of Hazardous Atmospheres, Version 5.2.3
Spill Duration			One hour spill duration is used by ALOHA. This one hour spill duration is assumed to correspond to the ERPG limits for one hour exposure.
Puddle Calculations			Models evaporation from a puddle formed on the ground and that is not changing in area. Models 100% pure chemical.
Default LOC			ERPG-1
TLV-TWA			ERPG-2
IDLH			ERPG-2
Direct Calculations			Model uses the Gaussian dispersion model to estimate plume concentration when the source strength is known or estimated. It allows for estimation of chemicals that are less than 100% concentration.
Vapor Model			Estimating Releases & Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form, EPA 560 4-88-002, 12/87

Parameter	Input Value	Units	Notes and Assumptions
Spill Calculations Volume of Spill, ft^3=(Area of Spill, ft)(Spill Depth, ft) Volume of spill, gal=(area of Spill, ft)(Depth of Spill, ft) (7.48 gal/ft^3) Height of spill (Dissolved solids outside only) = 3 meters			

4.2.5.2 Environmental Radiological Safety Consequence Analysis

This section describes how the environmental-radiological safety consequence evaluations were performed in determining potential public exposure from the BPF process.

Generic Assumptions, Input Parameters, & Calculations

The environmental-radiological consequence assessments evaluated the scenarios against four of the criteria listed in 10 CFR 70.61 that define intermediate and high consequences. The first two criteria (paragraph (b)(2) and paragraph (c)(2) criteria) involve the TEDE to an individual outside the controlled area boundary; where a high consequence event has a TEDE ≥ 25 rem and an intermediate consequence event has a TEDE that is ≥ 5 rem and < 25 rem. The third criteria (paragraph (c)(3)) involves a 24-hour averaged release of radioactive material outside the restricted area in concentrations exceeding 5,000 times the values of Table 2 of Appendix B to 10 CFR 20, which is also referred to as the Appendix B criteria in this document. Exceeding the Appendix B criteria results in an intermediate consequence level. The fourth criteria (paragraph(b)(3)) involves a soluble uranium intake of > 30 mg for an individual outside the controlled area boundary resulting in a high consequence.

Each environmental-radiological scenario was evaluated against the multiple criteria, and in some cases, multiple pathways, to determine a single comprehensive consequence level for the scenario. The highest consequence level associated with the multiple evaluation criteria was chosen as the bounding consequence level for a scenario. When multiple pathways existed, the TEDEs and the soluble uranium intakes were summed for all pathways and compared to the evaluation criteria, even though the locations of the maximally exposed offsite receptors may have been dramatically different. When the sums of these parameters do not result in an intermediate or high consequence level, the scenario is conservatively determined to have a low consequence level. When the sum of either the TEDE or the soluble uranium intake parameters is the sole criteria that indicates that the consequence level is intermediate or high, the individual pathways would have needed to be evaluated more closely. There were no scenarios for the BPF that required a closer evaluation. The highest environmental-radiological consequence levels were only intermediate, and the Appendix B criteria for the liquid migrating offsite was always the initial trigger for the intermediate consequences.

There were four common scenarios for the BPF that generic consequence evaluation spreadsheets were created for. In each of these generic spreadsheets, there are numerous input parameters that can be specified to evaluate a specific or generic consequence scenario. The four common consequence scenarios

included: indoor radioactive liquid spills, outdoor radioactive liquid spills, radioactive material dispersions, and unmitigated gaseous effluent releases.

Typically, the generic scenarios were used to establish bounding calculations for a type of consequence scenario. Types of consequence scenarios were usually based on parameters such as material type, chemical form, and physical state. When bounding calculations were used for the consequence evaluations, the bounding scenarios were not specific to a consequence scenario listed in the PHA tables. Each of the items in the PHA tables with a potential radiological consequence was then grouped under the appropriate bounding scenario evaluation. The grouping was based on the worst case consequence listed for a given item in the PHA tables.

Generic air dispersion calculations were performed for a number of airborne release scenarios. Two atmospheric dispersion computer models were used for these evaluations, HotSpot Version 8.03 and CAP88-PC Version 2.0. The HotSpot computer model was used for release scenarios with a duration of 24 hours or less. When release durations exceed 24 hours, the HotSpot manual suggests using other models for long-term durations, such as the CAP88-PC computer model. As a result of this recommendation, the CAP88-PC model was used in conjunction with an adjustment factor for release scenarios with a duration greater than 24 hours and less than 1 year. Using CAP88-PC in conjunction with an adjustment factor is consistent with NFS procedures for estimating offsite doses. NFS routinely uses an adjustment factor with CAP88-PC to estimate doses for release periods that are less than 1 year in duration (e.g., quarterly dose assessments, semiannual dose assessments).

Calculations were performed for the following atmospheric dispersion scenarios: 1) releases from the 703 Stack, 2) releases from the BPF roof, 3) ground level point source releases near the BPF, and 4) releases from outdoor area sources near the BPF. All of these calculations were performed for 1 Ci quantities of a given radionuclide to establish a unit dose conversion factor for a specific radionuclide and a specific atmospheric dispersion scenario. These calculations also determined the atmospheric dispersion factors, which are mostly dependent on the physical form of the radionuclide.

All radionuclide concentrations were obtained from the document titled *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (NFS, 2002), with the exception of the radionuclide ratios for the raffinate sources. The radionuclide concentrations for the raffinate sources were recalculated for different uranium concentrations, and the new calculations have been included in consequence evaluations for the Solvent Extraction Process.

Doses were calculated for the radionuclides that accounted for at least 90% of the total dose associated with an airborne or liquid release. The major dose contributing radionuclides were determined from the release estimates provided in

the document titled *ISA Source Term Data and Radioactive Effluent Estimates for the TVA Project* (NFS, 2002). The doses associated with Pathway 3 for the radioactive liquid spills were typically calculated for all radionuclides involved, because each potential radionuclide's impact on the sum-of-fractions (SOF) calculation was not known prior to the SOF calculation.

The inhalation rate used for dose calculations was 2.0E+04 ml/min, which was obtained from 10 CFR 20, Appendix B. A radionuclide's most conservative solubility class was used for the dose calculations. However, the most appropriate solubility class for a uranium compound was used for the soluble uranium intake calculations. Scenarios where a mixture of uranium compounds was present, the worst case solubility class was typically used, unless one compound dominated the mixture. Table 4-7 provides a summary of the uranium compounds included in these evaluations and their corresponding solubility classes.

Table 4-7
Summary of Uranium Compounds

Compound Name	Chemical Formula	Solubility Class
uranium metal	U	Y
uranium dioxide	UO_2	W
uranium trioxide	UO_3	D
uranium oxide	U_3O_8	W
uranyl nitrate	$UO_2(NO_3)_2$	D
uranium/aluminum	UAl	Y
sodium diurante	$Na_2U_2O_7$	Y

Indoor Radioactive Liquid Spill Scenarios

There are three major pathways that contribute to the performance criteria for large spill scenarios. Pathway 1 is an inhalation pathway that involves the spilled radioactive liquid inside Building [redacted] which becomes airborne and is released outside the controlled area. Pathway 1 includes the initial suspension from the spill event and any subsequent suspension from the resulting contamination, which may occur until the building is decontaminated. Pathway 2 is another inhalation pathway that involves the spilled radioactive liquid that manages to migrate outside the building. Pathway 2 only accounts for the subsequent suspension from the resulting outdoor contamination, which may occur until the area is decontaminated. Pathway 3 is an ingestion pathway that involves the spilled radioactive liquid that migrates outside the controlled area boundary and into a surface water stream. Pathway 3 determines the consequence level for the Appendix B criteria at the restricted area boundary, where as, the consequence levels for the offsite TEDE and soluble uranium intake criteria are determined at the nearest point of water usage.

The properties of water (density, viscosity) were generically used for all non-radioactive liquids involved in a spill, because the non-radioactive liquids were either water or mostly consisted of water.

Overfills of a radioactive source term with a non-radioactive liquid were limited to 5[redacted]allons (18,913 L). This overfill is equivalent to a 13.9-hour overfill at 6 gal/min for a ½-in diameter liquid line. A [redacted]gallon overfill was determined to be bounding by the licensing specialist, for a scenario that does not require any human intervention to end the event.

The BPF was divided into four areas for the liquid spill evaluations: the low-enriched uranium (LEU) area, the main building area, the chimney area, and the solvent extraction (SX) area. Spill scenarios that could occur in either the main building area or the chimney area used the sum of the square footage of the LEU area, main building area, and the chimney area for the consequence evaluations. Spill scenarios that could occur in the SX area used the sum of the square footage of the SX area, LEU area, main building area, and the chimney area for the consequence evaluations.

The maximum spill heights were limited to 5 m (16.4 ft) to be consistent with the Health Physics consequence evaluations. The event duration for the indoor portion of a spill was limited to 24 hours after the event is stopped. A 24-hour decontamination period was deemed reasonable because of the incentives to get the facility back on line. Decontamination in this section means decontaminating the spill area to a point where it can no longer contribute to doses and/or exposure outside the controlled area boundary. The event duration for any outdoor portion of a spill was limited to 90 days. A period of 90 days was used because outdoor spills typically require much more time to decontaminate and decontamination should be able to be completed within 90 days.

Indoor spills utilized a combination of two airborne release fractions (ARFs), to account for the two release mechanisms. Airborne releases from an indoor spill can be generated from two mechanisms, the initial spill and the subsequent suspension until decontamination.

A runoff coefficient was used to estimate how much of an outdoor liquid spill could run into the stormwater system and offsite. The U.S. Environmental Protection Agency's publication titled Toxic Chemical Release Inventory Reporting Forms and Instructions (EPA, 2001) was used as the reference for the runoff coefficients. The areas immediately outside of the BPF and downstream of the building are mostly asphalt, roughly surfaced concrete, and crushed stone. The average runoff coefficient for asphaltic terrain, 0.825, was used for these evaluations, because it was representative of the most typical terrain a spill would flow over.

Liquid spills that occur at or near the BPF will eventually runoff into NFS' stormwater drainage system. The stormwater for the NFS site drains into Banner Spring Branch (BSB), where any stormwater or spill would be diluted by the BSB flow prior to leaving the Controlled Area.

Liquid spills that are large enough to reach NFS' stormwater drainage system can travel offsite by draining into BSB, then into Martin Creek, then into North Indian Creek, and into the Nolichucky River. The Nolichucky River's flow rate was used for calculating the potential radionuclide concentrations in the Nolichucky River for Pathway 3, and the subsequent doses and soluble uranium intakes.

Pathway 3 uses an ingestion rate to calculate doses and intakes. The ingestion rate used for the radioactive liquid spill scenarios was 2.0 L/day, which is equivalent to the ingestion rate of 7.3E+05 ml/yr provided in 10 CFR 20, Appendix B. This pathway also uses the values in 10 CFR 20, Appendix B, Table 2, Column 2 to estimate the potential doses for the ingestion intake pathway, because these values are based on a 50 mrem/yr TEDE when ingested continuously over the course of a year.

The screening model provided by NCRP Report 123 (NCRP, 1996a and NCRP, 1996b) was not used for these calculations because the NCRP model was not designed to handle the transport and dispersion of a contaminant through multiple tributaries. In addition, the NCRP model only uses the stream flow rate at the point of discharge for its dilution calculations rather than the flow rate at the nearest point of water usage, which even for a single stream scenario is very conservative. As previously stated, the BPF's spill scenarios involve the transport and dispersion of the contaminants through four waterways before reaching the nearest point of water usage. The initial waterway that the contaminants would enter has an insignificant flow rate compared to the subsequent waterways. In these calculations, the potential spills were diluted with Nolichucky River's flow rate instead of the flow rate from the first waterway the contaminants enter (i.e., Banner Spring Branch). It was assumed that complete mixing of the contaminants with the Nolichucky River water occurs prior to reaching the nearest point of water usage. This assumption was based on the fact that the contaminants are initially discharged into a relatively small waterway that progressively increases in size as each waterway drains into a larger waterway. The assumption was also based on the fact that these waterways have many twists, bends, and obstructions that would also facilitate complete mixing.

Table 4-8
Environmental Radiological Safety Consequence Analysis Summary

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		U Metal Sampling	
1	Radioactive Material Dispersion Scenario	UMS (39.2, 39.3, 39.4, 39.5, 39.8, 39.11, 39.12, 39.13)	Low
See Note a	No Environmental Radiological Consequence	UMS(39.14)	None
Note: a - The Environmental Health Physicist has determined that no environmental-radiological consequences can result from the consequence listed in the PHA table. The potential external doses to offsite members of the public are the same for repackaging the U-metal ingots as they would be for using an unshielded cart. It is impossible for the external doses attributable to this process to approach the 5 rem threshold for an intermediate consequence; therefore no consequence evaluations were performed.			
		U Metal Oxidation and Dissolution	
1	Indoor HE UN Solution Spill Scenario involving ≤ 5,300 L (1,400 gal) HE UN solution	1UMD (1.1, 1.19, 1.44, 1.47, 1.48, 1.50, 1.54, 1.59, 1.79[b], 1.80, 1.82[b], 1.86, 1.87, 1.107, 1.109[b], 1.111, 1.113, 1.114, 1.116, 1.120, 1.124, 1.128, 1.134, 1.135, 1.136, 1.150, 1.152, 1.154, 1.156[b], 1.158, 1.162, 1.182) 2UMD (2.1, 2.19, 2.44, 2.47, 2.48, 2.50, 2.54, 2.59, 2.79[b], 2.80, 2.82[b], 2.86, 2.87, 2.107, 2.109[b], 2.111, 2.113, 2.114, 2.116, 2.120, 2.124, 2.128, 2.134, 2.135, 2.136, 2.150, 2.152, 2.154, 2.156[b], 2.158, 2.162, 2.182) 3DT (3.10, 3.13, 3.14, 3.18, 3.19, 3.20, 3.21, 3.23, 3.24, 3.25, 3.36, 3.37, 3.43, 3.46, 3.47, 3.49, 3.50, 3.52, 3.53, 3.59) 7DT (4.14, 4.16, 4.19, 4.20, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33, 4.35, 4.36, 4.37, 4.41, 4.47, 4.48, 4.49, 4.53)	Low
2	Indoor HE UN Solution Water Overfill Spill Scenario involving ≤ 175 L (46 gal) HE UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	1UMD (1.53, 1.56, 1.106) 2UMD (2.53, 2.56, 2.106)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
3	Indoor HE UN Solution Water Overfill Spill Scenario: involving an unlimited source of HE UN solution and ≤ 18,925 L ([redacted]) of non-radioactive liquid	1UMD (1.147, 1.148, 1.156) 2UMD (2.147, 2.148, 2.156) 3DT (3.1, 3.2, 3.3, 3.11, 3.33) 7DT (4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.17, 4.45)	Intermediate
4	HE U_3O_8 Dispersion Scenario: involving ≤ 530 lb (240.4 kg) HE U_3O_8	1UMD (1.62, 1.63, 1.64, 1.65, 1.68, 1.71, 1.74, 1.76, 1.137, 1.138, 1.149, 1.164) 2UMD (2.62, 2.63, 2.64, 2.65, 2.68, 2.71, 2.74, 2.76, 2.137, 2.138, 2.149, 2.164)	Low
5	HE U Metal Dispersion Scenario: involving a nearly unlimited source of HE U metal	1UMD (1.171) 2UMD (2.171)	Low
See Note a	Items that no longer have any credible scenarios	1UMD (1.67, 1.73) 2UMD (2.67, 2.73)	N/A
Note: a: = The fire or explosion consequence was deemed not credible by the fire protection consequence evaluation; N/A = not applicable. b: = The explosion consequence was deemed not credible by the industrial safety consequence evaluation.			
		HSSA	
1	Radioactive Material Dispersion Scenario	HSSA (28.7, 28.13, 28.14, 28.15)	Low
2	Thinner Rack/Cart Holder Wall Thickness Scenario	HSSA (28.16)	Low
		UAl_x Dissolution	
1	Indoor HE UN Solution Spill Scenario: involving ≤ 5,300 L (1,400 gal) HE UN solution	1UALS (33.1, 33.3, 33.5, 33.7, 33.11, 33.12, 33.13, 33.14, 33.16, 33.58, 33.62, 33.66, 33.69, 33.71, 33.74, 33.75, 33.77, 33.89, 33.90, 33.95, 33.104, 33.109) 2UALS (34.1, 34.3, 34.5, 34.7, 34.11, 34.12, 34.13, 34.14, 34.16, 34.55, 34.59, 34.62, 34.64, 34.67, 34.68, 34.70, 34.82, 34.83, 34.88, 34.96, 34.102, 34.106) UALAC (37.5, 37.6, 37.9, 37.10, 37.11, 37.13, 37.16, 37.17, 37.18, 37.28, 37.29, 37.33, 37.36, 37.37, 37.39, 37.40, 37.42, 37.46)	Low
2	Indoor HE UN Solution Water Overfill Spill Scenario: involving ≤ 175 L (46 gal) HE UN source term and 18,925 L ([redacted]) of non-radioactive liquid	1UALS (33.10, 33.19, 33.21, 33.29, 33.97) 2UALS (34.10, 34.19, 34.21, 34.29, 34.97) 1UALS (33.21) 2UALS (34.21)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
3	Indoor HE UN Solution Water Overfill Spill Scenario: involving an unlimited source of HE UN solution and ≤18,925 L ([redacted] gal) of non-radioactive liquid	UALAC (37.3, 37.38)	Intermediate
4	Indoor HE UAL Dissolver Solution Spill Scenario: involving ≤ [redacted]) HE U solution	1UALD (29.22, 29.27, 29.31*, 29.33*, 29.35*, 29.46, 29.60, 29.63*, 29.64*, 29.68*, 29.76*, 29.84, 29.89) 2UALD (30.22, 30.27, 30.31*, 30.33*, 30.35*, 30.46, 30.60, 30.63*, 30.64*, 30.68*, 30.76*, 30.84, 30.89) 3UALD (31.22, 31.27, 31.31*, 31.33*, 31.35*, 31.46, 31.60, 31.63*, 31.64*, 31.68*, 31.76*, 31.84, 31.89) 4UALD (32.22, 32.27, 32.31*, 32.33*, 32.35*, 32.46, 32.60, 32.63*, 32.64*, 32.68*, 32.76*, 32.84, 32.89) 1UALS (33.24*, 33.27, 33.28, 33.87, 33.107, 33.108, 33.111) 2UALS (34.24*, 34.27, 34.28, 34.80, 34.105, 34.106, 34.109)	Low
5	Indoor HE UAL Dissolver Solution Water Overfill Spill Scenario: involving ≤9,600 L (2,536 gal) of HE U solution and ≤18,925 L (5,000 gal) of non-radioactive liquid	1UALD (29.16*, 29.20, 29.91) 2UALD (30.16*, 30.20, 30.91) 3UALD (31.16*, 31.20, 31.91) 4UALD (32.16*, 32.20, 32.91)	Low
6	Indoor Caustic Discard Solution Spill Scenario: involving ≤ [redacted] gal) caustic discard solution	1UALS (33.33, 33.34, 33.35, 33.36, 33.37, 33.39, 33.40, 33.41, 33.42, 33.43, 33.45, 33.46, 33.47, 33.48, 33.49, 33.50, 33.51) 2UALS (34.33, 34.34, 34.35, 34.36, 34.37, 34.39, 34.40, 34.41, 34.42, 34.43, 34.45, 34.46, 34.47, 34.48, 34.49, 34.50, 34.51) 1UALC (35.7, 35.8, 35.9, 35.12, 35.13, 35.14, 35.16, 35.17, 35.19, 35.20, 35.21, 35.25, 35.36, 35.40, 35.41, 35.42, 35.44, 35.48) 2UALC (36.7, 36.8, 36.9, 36.12, 36.13, 36.14, 36.16, 36.17, 36.19, 36.20, 36.21, 36.25, 36.36, 36.40, 36.41, 36.42, 36.44, 36.48)	Low
7	Indoor Caustic Discard Solution Water Overfill Spill Scenario: involving an unlimited source of caustic discard solution and ≤18,925 L (5,000 gal) of non-radioactive liquid	1UALC (35.3, 35.34) 2UALC (36.3, 36.34)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
8	H_2 Explosion Scenario involving 480 L (126.8 gal) of HEU solution	1UALD (29.23, 29.25, 29.26, 29.30, 29.78, 29.80, 29.88) 2UALD (30.23, 30.25, 30.26, 30.30, 30.78, 30.80, 30.88) 3UALD (31.23, 31.25, 31.26, 31.30, 31.78, 31.80, 31.88) 4UALD (32.23, 32.25, 32.26, 32.30, 32.78, 32.80, 32.88) CMST (38.16, 38.17, 38.18, 38.19, 38.20, 38.31, 38.32, 38.33, 38.34, 38.36, 38.47)	Low
9	H_2 Explosion Scenario involving 37,768 L (9,978 gal) of U solutions	1UALD (29.45, 29.48, 29.49, 29.57, 29.59, 29.66, 29.70, 29.84) 2UALD (30.45, 30.48, 30.49, 30.57, 30.59, 30.66, 30.70, 30.84) 3UALD (31.45, 31.48, 31.49, 31.57, 31.59, 31.66, 31.70, 31.84) 4UALD (32.45, 32.48, 32.49, 32.57, 32.59, 32.66, 32.70, 32.84)	Intermediate

Note:
a. The fire or explosion consequence was deemed not credible by the fire protection consequence evaluation.

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		Solvent Extraction	
1	Indoor, ≤400 g U/L HB UN Solution Spill Scenario: involving ≤ 5,300 l (1,400 gal) HE UN	SXFC (9.3, 9.13, 9.14, 9.21, 9.22, 9.25, 9.27, 9.28, 9.30, 9.31, 9.34, 9.37, 9.38, 9.44, 9.45, 9.46, 9.47, 9.50, 9.52, 9.53, 9.60, 9.62, 9.64) 1PX (10.3, 10.5, 10.6, 10.36, 10.37, 10.38, 10.46, 10.48, 10.50, 10.51, 10.52, 10.53, 10.54, 10.56, 10.58, 10.59, 10.60, 10.61, 10.62, 10.64, 10.65, 10.66, 10.68, 10.70, 10.72, 10.73, 10.74, 10.75, 10.76, 10.77, 10.78, 10.80, 10.81, 10.82, 10.83, 10.84, 10.85, 10.86, 10.88, 10.89, 10.90, 10.91, 10.92, 10.94, 10.95, 10.96, 10.97, 10.98, 10.99, 10.100, 10.103, 10.104, 10.105, 10.106, 10.107, 10.108, 10.109, 10.110, 10.112, 10.116, 10.119, 10.122, 10.124, 10.126, 10.129) 1PSW (11.2, 11.3, 11.6, 11.8, 11.10, 11.11, 11.12, 11.13, 11.14, 11.22, 11.24, 11.25, 11.27, 11.40, 11.41, 11.48, 11.49, 11.50, 11.51, 11.52, 11.53, 11.54, 11.55, 11.56, 11.57, 11.58, 11.59, 11.60, 11.61, 11.62, 11.63, 11.65, 11.67, 11.68, 11.69, 11.70, 11.71, 11.73, 11.74, 11.75, 11.77, 11.78, 11.79, 11.82, 11.83, 11.84, 11.85, 11.90, 11.91, 11.92, 11.93, 11.94, 11.95, 11.99, 11.101, 11.102, 11.103, 11.106, 11.107, 11.112, 11.114, 11.116) 1PE (12.28, 12.52, 12.53, 12.56, 12.59, 12.60, 12.61, 12.62, 12.63, 12.64, 12.65, 12.66, 12.67, 12.68, 12.69, 12.70, 12.72, 12.73, 12.74, 12.75, 12.79, 12.80, 12.81, 12.82, 12.83, 12.85, 12.89, 12.91, 12.95, 12.99, 12.100, 12.102, 12.103, 12.106, 12.107, 12.108, 12.110, 12.113, 12.114, 12.115, 12.116, 12.117, 12.118, 12.120, 12.121, 12.122, 12.128, 12.130, 12.132, 12.167, 12.179) 2PSX (13.2, 13.23, 13.24, 13.30, 13.32, 13.33, 13.34, 13.36, 13.38, 13.39, 13.40, 13.42, 13.43, 13.44, 13.46, 13.48, 13.49, 13.50, 13.51, 13.52, 13.53, 13.54, 13.56, 13.57, 13.58, 13.59, 13.60, 13.62, 13.63, 13.64, 13.65, 13.66, 13.67, 13.68, 13.69, 13.70, 13.77, 13.80, 13.82, 13.84, 13.86, 13.89, 13.91, 13.93) 2PSW (14.1, 14.2, 14.6, 14.8, 14.10, 14.11, 14.12, 14.13, 14.14, 14.22, 14.24, 14.25, 14.27, 14.40, 14.41, 14.48, 14.49, 14.50, 14.51, 14.52, 14.53, 14.54, 14.55, 14.56, 14.57, 14.58, 14.59, 14.60, 14.61, 14.62, 14.63, 14.65, 14.67, 14.68, 14.69, 14.70, 14.71, 14.73, 14.74, 14.75, 14.77, 14.78, 14.79, 14.82, 14.83, 14.84, 14.85, 14.90, 14.91, 14.92, 14.93, 14.94, 14.95, 14.99, 14.101, 14.103, 14.106, 14.108, 14.110, 14.111, 14.116) 2PE (15.28, 15.47, 15.50, 15.51, 15.54, 15.55, 15.56, 15.57, 15.58, 15.59, 15.60, 15.61, 15.62, 15.63, 15.64, 15.66, 15.67, 15.68, 15.69, 15.73, 15.74, 15.75, 15.76, 15.77, 15.79, 15.83, 15.85, 15.88, 15.91, 15.92, 15.94, 15.95, 15.96, 15.98, 15.99, 15.100, 15.102, 15.104, 15.106, 15.141, 15.153) SXSF (16.9, 16.14, 16.15, 16.16, 16.19, 16.27, 16.28, 16.29, 16.31, 16.37, 16.39, 16.40, 16.41, 16.44, 16.45, 16.52, 16.59) 1PRS (17.3, 17.5, 17.14, 17.15, 17.22, 17.24, 17.26, 17.27, 17.29, 17.31, 17.32, 17.33, 17.34, 17.45, 17.47, 17.51, 17.57, 17.61, 17.62, 17.76, 17.77, 17.79, 17.82, 17.83, 17.85)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		2PRS (18.9, 18.11, 18.12, 18.14, 18.16, 18.17, 18.18, 18.19, 18.22, 18.26, 18.27, 18.29, 18.30, 18.33, 18.34, 18.35) SXSC (19.9, 19.11, 19.12, 19.14, 19.15, 19.20, 19.22, 19.23) ECA (20.2, 20.4, 20.5, 20.7, 20.8, 20.10, 20.11, 20.17, 20.31, 20.32, 20.40, 20.41, 20.43) ECB (21.1, 21.3, 21.4, 21.6, 21.7, 21.13, 21.27, 21.28, 21.36, 21.37, 21.39) SXPS (22.3, 22.5, 22.30, 22.32, 22.34, 22.35, 22.36, 22.38, 22.40, 22.41, 22.43, 22.45, 22.46, 22.47, 22.48, 22.49, 22.50, 22.51, 22.52, 22.53, 22.55, 22.59, 22.61, 22.63, 22.67, 22.70, 22.76) 1SXCM (23.34, 23.55) 2SXCM (24.2, 24.7, 24.16, 24.18, 24.20, 24.22, 24.52) VKC (25.3, 25.5, 25.6)	
2	Indoor, ≤ 66.6 g U/L HE UN Solutions Water Overfill Spill Scenario involving ≤ 3,400 L (898 gal) HE UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	1PSW (11.28, 11.30) 1PE (12.24, 12.30, 12.32) 2PSW (14.28, 14.30) 2PE (15.24, 15.26, 15.30, 15.32, 15.89) 2PRS (18.2) SXSC (19.5)	Low
3	Indoor, ≤ 400 g U/L HE UN Solutions Water Overfill Spill Scenario involving ≤ 495 L (131 gal) HE UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	SXFC (9.5, 9.9, 9.11, 9.65) 1PX (10.7, 10.9, 10.11, 10.13) 1PSW (11.1, 11.26, 11.80) 1PE (12.26, 12.34, 12.45) 2PSX (13.3, 13.5, 13.7, 13.75) 2PSW (14.26, 14.80, 14.102) 2PE (15.34) SXSF (16.1, 16.55, 16.57) 1PRS (17.9, 17.11, 17.19, 17.65) SXPS (22.26, 22.28, 22.72, 22.74)	Low
4	Red Oil Incident	1PX (10.2, 10.55, 10.57, 10.63) 1PE (12.88, 12.90, 12.92, 12.185, 12.186, 12.187) 2PSX (13.35, 13.37, 13.41, 13.71, 13.90) 2PE (15.82, 15.84, 15.86, 15.155, 15.156, 15.157)	High
See Note B	No Environmental-Radiological Consequence	1PE (12.94) 2PE (15.88)	

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
Notes: a - A red oil incident was assumed to have a high consequence, because of its inherent severity and because the Fire Protection Safety Evaluation did not provide details on the amount of damage such an incident could potentially cause. b - The Environmental Health Physicist has determined that no environmental-radiological consequences can result from the consequences listed in the PHA table.			
		Downblending	
1	Indoor LE UN Solution Spill Scenario: involving ≤ 2,290 L (605 gal) LE UN	UDB (5.55, 5.94, 5.120, 5.139, 5.141, 5.142, 5.150) UND (6.199) UNT (7.20, 7.23, 7.24, 7.50, 7.56, 7.61, 7.68)	Low
2	Indoor LE UN Solution Spill Scenario: involving > 2,290 L (605 gal) to ≤ 220,000 L (58,124 gal) LE UN	UDB (5.78, 5.83, 5.84, 5.91, 5.93, 5.97, 5.100, 5.103, 5.138) UNT (7.8, 7.12, 7.13, 7.17, 7.19, 7.22)	Intermediate
3	Indoor LE UN Solution Water Overfill Spill Scenario: involving ≤ 1,600 L (423 gal) LE UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	None	Low
4	Indoor LE UN Solution Water Overfill Spill Scenario: involving an unlimited LE UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	UDB (5.80, 5.88, 5.116, 5.129) UNT (7.5, 7.45)	Intermediate
5	Outdoor LE UN Solution Spill Scenario: involving ≤ 1,190 L (314 gal) LE UN	None	Low
6	Outdoor LE UN Solution Spill Scenario: involving > 1,190 L (314 gal) to ≤ 49,000 L (12,946 gal) LE UN	UNT (7.38)	Intermediate
7	Indoor Nat. UN Solution Spill Scenario: involving ≤ 8,900 L (2,351 gal) Nat. UN	UDB (5.52, 5.54, 5.57, 5.122, 5.126, 5.128, 5.140, 5.143, 5.144) UND (6.27, 6.41, 6.59, 6.60, 6.62, 6.63, 6.64, 6.66, 6.68, 6.69, 6.71, 6.72, 6.80, 6.81, 6.84, 6.100, 6.101, 6.102, 6.104, 6.106, 6.110, 6.158, 6.165, 6.172, 6.176, 6.177, 6.179, 6.184, 6.186, 6.187, 6.188, 6.189, 6.190, 6.193, 6.196, 6.211, 6.212, 6.221, 6.224, 6.225, 6.226, 6.227, 6.228, 6.233, 6.235, 6.236, 6.237, 6.238, 6.241, 6.242, 6.243, 6.261, 6.265, 6.266, 6.268, 6.272, 6.273)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
8	Indoor Nat. UN Solution Water Overfill Spill Scenario: involving ≤ 15,000 L (3,963 gal) natural UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	UND (6.39, 6.46, 6.190)	Low
9	Outdoor Nat. UN Solution Spill Scenario: involving ≤ 6,900 L (1,823 gal) natural UN	UDB (5.132) UNT (7.41, 7.47, 7.54)	Low
10	Outdoor Nat. UN Solution Spill Scenario: involving > 6,900 L (1,823 gal) to ≤ 95,000 L (25,099 gal) natural UN	UNT (7.3, 7.31, 7.37, 7.39, 7.42, 7.44, 7.45, 7.53)	Intermediate
11	Indoor HE UN Solution Spill Scenario: involving ≤ 5,300 L (1,400 gal) HE UN	UDB (5.3, 5.5, 5.13, 5.34, 5.44, 5.46, 5.47, 5.146, 5.147) UMM (8.1, 8.3, 8.5, 8.10, 8.15, 8.16, 8.17, 8.19, 8.20, 8.22, 8.23, 8.26, 8.32, 8.33, 8.35, 8.36)	Low
12	Indoor HE UN Solution Water Overfill Spill Scenario: involving ≤ 175 L (46 gal) HE UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	None	Low
13	Indoor HE UN Solution Water Overfill Spill Scenario: involving an unlimited HE UN source term and 18,925 L (5,000 gal) of non-radioactive liquid	UDB (5.8, 5.14, 5.16, 5.18, 5.20, 5.22, 5.24, 5.26, 5.28, 5.30, 5.32) UMM (8.12)	Intermediate
14	Indoor UO3 Dispersion (Spill) Scenario: involving ≤ 88,000 lb (40,000 kg) of UO3	UND (6.1*, 6.2*, 6.3*, 6.5*, 6.6*, 6.7*, 6.8*, 6.9*, 6.10*, 6.11*, 6.12*, 6.18*, 6.22*, 6.23*, 6.25, 6.26, 6.29*, 6.30, 6.32*, 6.35*, 6.246, 6.278, 6.279, 6.280, 6.282, 6.283, 6.285, 6.286, 6.289)	Low
15	Indoor UO3 Dispersion (Spill & Fire) Scenario: involving ≤ 43,000 lb (19,545 kg) of UO3	UND (6.20, 6.21)	Low
16	Outdoor UO3 Dispersion (Spill) Scenario: involving ≤ 11,100 lb (5,045 kg) of UO3	UND (6.281)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
See Note b	LE UN Solution Spill Scenario That Occurs at the UNB, involving ≤ 18,925 L (5,000 gal) LE UN	UNT (7.25, 7.35, 7.51)	Low
Notes:			
a. The potential fire and/or explosion scenarios for these items have been deemed not credible by the fire protection consequence evaluation, and these dispersion mechanisms were not included in the scenario evaluations. Item 7.43 was deemed not credible by the fire protection consequence evaluation and is therefore not included in the consequence summary.			
b. This scenario is bounded by the environmental consequence analyses performed for the Uranyl Nitrate Storage Building's ISA. All of the environmental consequences for the Uranyl Nitrate Storage Building were determined to be a low consequence.			
c. Significantly different scenarios can occur for Item 7.45, because this item can occur for both drawings 333-F0552-D and 333-F0554-D. As a result of this, Item 7.45 is listed under both Scenarios 4 and 10 to represent the worst case scenario for each drawing.			
		Liquid Discards	
1	Outdoor SX Condensate Solution Spill Scenario: involving ≤ 660,000 L (174,373 gal) SX condensate solution	ND (26.1, 26.2, 26.4, 26.12, 26.26, 26.27, 26.31, 26.32, 26.37, 26.39, 26.41, 26.43, 26.46, 26.50, 26.51)	Low
2	Outdoor SX Condensate Solution Water Overfill Spill Scenario, involving an unlimited source of SX condensate solution and ≤ 18,925 L (5,000 gal) of non-radioactive liquid	ND (26.21, 26.23, 26.24, 26.42)	Low
3	Outdoor Caustic Discard Solution Spill Scenario: involving ≤ 660,000 L (174,373 gal) Caustic Discard Solution	CD (27.1, 27.2, 27.4, 27.12, 27.17, 27.19, 27.27, 27.29, 27.31, 27.32, 27.37, 27.39, 27.41, 27.43, 27.46, 27.48, 27.49)	Low
4	Outdoor Caustic Discard Solution Water Overfill Spill Scenario, involving an unlimited source of caustic discard solution and ≤ 18,925 L (5,000 gal) of non-radioactive liquid	CD (27.21, 27.24, 27.26, 27.42)	Low

Evaluation Number	Scenario Evaluated	Accident Sequence Number(s)	High, Intermediate or Low Consequence
		Ventilation System	
1	Unmitigated Gaseous Effluent Scenario: Unmitigated releases from all BPF processes	PV(44.1, 44.2, 44.5, 44.7, 44.9, 44.11, 44.17, 44.18, 44.20, 44.22, 44.23, 44.24) PS(45.10, 45.14, 45.22, 45.24, 45.26, 45.28, 45.29, 45.31, 45.32, 45.34, 45.38, 45.40, 45.41, 45.52, 45.67, 45.109, 45.111, 45.127, 45.143, 45.144)	Low
2	Unmitigated Gaseous Effluent Scenario: Scenario associated with Item 44.21	PV(44.3, 44.21)	Low
3	Indoor Scrubber Solution Spill Scenario: involving ≤ 80,000 L (21,136 gal) of scrubber solution	PS(45.17, 45.19, 45.21, 45.25, 45.33, 45.64, 45.70, 45.75, 45.78, 45.79, 45.80, 45.81, 45.83, 45.84, 45.87, 45.88, 45.89, 45.91, 45.92, 45.95, 45.96, 45.106, 45.107, 45.112, 45.126, 45.136, 45.138, 45.142)	Low
4	Indoor Scrubber Solution Water Overfill Spill Scenario: involving an unlimited source of scrubber solution and ≤ 18,925 L (5,000 gal) of non-radioactive liquid	PS(45.5, 45.7, 45.11, 45.13, 45.60, 45.66, 45.101)	Low
5	Indoor POG Condensation Spill Scenario: involving ≤ 750,000 L (198,151 gal) of POG condensation	PV(44.14) PS(45.46)	Low
		Utilities	
1	Cooling Water Supply Fail Off Scenario:	UTD(40.1, 40.2, 40.4, 40.7)	Low
2	Nitrogen Supply Fail Off Scenario:	UTD(40.9, 40.12, 40.16)	Low
3	Plant Air Supply Fail Off Scenario:	UTD(40.26, 40.28, 40.32)	Low
4	Process Water Supply Fail Off Scenario:	UTD(40.49, 40.50, 40.52, 40.56)	Low

4.2.6 External Event Consequences

This section addresses potential BPF accidents initiated by natural phenomena or other significant hazards external to BPF operations. Natural phenomena events include consideration of earthquakes, tornadoes, wind and storm conditions, floods, and lightning strikes. Other external hazards include consideration of nearby transportation, business, or site initiators including: CSX Transportation Railroad, Carolina Avenue vehicle traffic, airport traffic, Studsvik Processing Facility, and Bulk Chemical Storage.

Earthquake

Potential seismic activity at the NFS site is addressed in Section 1.5.2, Seismology. Due to the moderate level of seismic activity, and implementation of SBC 1999 code requirements for the BPF structural features, an earthquake is not expected to result in significant consequences compared to the Section 7 exposure criteria. Compliance with code requirements is addressed by designation of appropriate IROFS and management measures in Section 6 of this report.

Winds and Storms

As discussed in Section 1.3.2 of this report, the BPF structural features have been designed to meet the SBC 1999 code requirements for wind load factors. Due to this design requirement and designation of corresponding IROFS and management measures, winds and storms are not a significant concern for BPF operations.

Tornadoes

The potential risk of tornado activity at the NFS site is addressed in Section 1.3.3 of this report. Due to the low occurrence of tornadoes in the Unicoi County area and topography of the NFS site, a damaging tornado is not a significant concern for BPF operations.

Lightning

As discussed in Section 1.3.4, the BPF is designed in accordance with the Lightning Protection Code (NFPA 780) and, therefore, lightning strikes would not be a significant concern for BPF operations. There are no credible accident scenarios that result in an intermediate or high consequence event as a result of a lightning strike.

Flood

Based on the flood analysis provided in Section 1.4 of this report, a 100-year flood would not have significant consequences for BPF operations.

CSX Transportation Railroad Yard

Potential hazards associated with the CSX Transportation railroad yard are addressed in Section 1.2.1.2 of this report. Considering the low speed of the trains in the yard, the significant distance from the BPF, extensive rail transportation requirements, and low incident record in the Erwin yard near NFS, the CSX Transportation railroad is not considered to be a significant concern for BPF operations.

Carolina Avenue

The potential hazards associated with Carolina Avenue which runs parallel to the east property boundary of the NFS Site are addressed in Section 1.2.1.4 of this report. Considering the distance from the controlled area, and the security barrier and fencing, vehicle traffic on Carolina Avenue is not a significant concern for BPF operations.

Local and Regional Airports

Potential hazards associated with the Tri-Cities Regional Airport and other local airports are addressed in Section 1.2.1.3 of this report.

Due to the size, distance, and flight patterns of these airports, they are not a concern for BPF operations.

Studsvik Processing Facility

Potential hazards associated with the Studsvik Processing Facility (SPF) are addressed in Section 1.2.1.1 of this report.

Because of its low source term, and distance from Building 333, the SPF constitutes a low hazard facility. Therefore, it is not considered a significant concern for BPF operations.

Bulk Chemical Storage

NFS bulk chemical storage (BCS) supplies are listed in Table 2-1 of Section 2. The BCS area is protected by dikes sufficient to hold the stored volume. The dikes limit or prevent potential spills from affecting on site personnel or off-site public. Specific ISA analysis of these hazards will be conducted and submitted with the ISA summary for the remainder of the plant.

Approximately 360 feet south of the BPF, there is a 1,500-gallon liquid hydrogen tank and a backup bank of six (6) horizontal tanks containing gaseous hydrogen (each tube is approximately 54 cubic feet). In the same area, there is a 1,000-

gallon liquefied propane gas (LPG) tank. Also, the delivery truck routes for both hydrogen and propane are approximately 350 feet from the BPF.

The primary exposure from these tanks and delivery trucks is from a boiling liquid expanding vapor explosion (BLEVE). A BLEVE creates a large rising fireball of short duration, which presents a radiant heat and burn injury exposure to people who may be outside and not in fire-rated protective clothing. A BLEVE does not produce remote overpressures and presents an insignificant thermal exposure from a property damage standpoint.

A hydrogen unconfined vapor cloud explosion (UVCE) is not a credible event due to the vapor density and dispersion characteristics of hydrogen. The LPG tank size (1,000 gallons), and location (in the open), make the likelihood of an UVCE highly unlikely. Therefore, the outside hydrogen and propane tanks present an insignificant exposure to nearby process operations.

4.3 RISK ASSESSMENT

This section provides justification for determining that Intermediate and High consequence events, as identified in Section 4.2, are Unlikely or Highly Unlikely as required by 10 CFR 70.61. For each unmitigated intermediate or high consequence event identified in Section 4.2, engineered or administrative safety controls are defined to ensure that the likelihood of the postulated events is very low (unlikely or highly unlikely). The methodology for determining that events are unlikely or highly unlikely is defined in Section 5.2.3, Risk Categorization. Additional risk assessment methodology for criticality safety scenarios is documented in the process NCSEs. The results of the BPF Risk Assessment are documented in the following tables.

Table 4-9
Criticality Safety Risk Index Table

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
U-METAL DISSOLUTION						
4.1.1.4.1 Container spacing upset with storage racks with One Operator Handling Portable Containers	Container spacing upset with storage racks See IROFS as Appropriate No credit for duration H/X limit exceeded EE=-1	BPF-4 or BPF-5 (-2) BPF-6 (-2)	Unc T = -3 Con T = -5	Unc = 2 Con = 1	3 3	6 3
4.1.1.4.2 Container spacing upset with storage racks with One Operator Handling Portable Containers	Container spacing upset with storage racks (BPF-4 or BPF-5) IE=-2 Mass limit exceeded EE=-1	BPF-7 (-2) BPF-8 (-2)	Unc T = -3 Con T = -7	Unc = 2 Con = 1	3 3	6 3
4.1.1.4.3 Container spacing upset with storage racks with Two or More Operators Handling Portable Containers	Container spacing upset with storage racks See IROFS as Appropriate No credit for duration H/X limit exceeded EE=-1	BPF-5 (-2) BPF-6 (-2)	Unc T = -1 Con T = -5	Unc = 1 Con = 1	3 3	3 3
4.1.1.4.4 Container spacing upset with storage racks with Two or More Operators Handling Portable Containers	Container spacing upset with storage racks (BPF-5) IE=-2 Mass limit exceeded EE=-1	BPF-7 (-2) BPF-8 (-2)	Unc T = -5 Con T = -7	Unc = 1 Con = 1	3 3	3 3
4.1.2 Too much material in containers placed on storage rack	Overloaded Container 10 kg over limit IE=-2	BPF-7 (-2) BPF-8 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.5.4.1 Too much moderator is present in containers on a rack and spacing upset 4.1.1	Container H/X Exceeded IE=-1	BPF-4 or BPF-5 (-2) BPF-6 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.5.4.2 Too much moderator is present in containers on a rack and spacing upset 4.1.1	Container H/X Exceeded IE=-1	BPF-6 (-2) BPF-4 or BPF-5 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.7.4.1 SNM Solution Spill/Leak and Collection in Unfavorable geometry container	SNM Solution Spill/Leak IE=-1	BPF-1 (-2) BPF-2 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.7.4.2 SNM Solution Over-flow and Collection in Unfavorable geometry container	SNM Solution Over-flow IE=-1	BPF-1 (-2) BPF-2 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.7.4.3 Solution Line Leaks Into Voids In Building Walls	Leak from process solution line See IROFS	BUM-7(P) (-2) Dur=-1 BUM-5(P) (-4)	Unc T = -3 Con T = -6	Unc = 2 Con = 1	3 3	6 3
4.1.8 SNM Backflow into chemical supply lines	Motive backflow force IE=-1 Loss of supply pressure EE=-1	BUM-8(P) (-4) BUM-9(A) (-2)	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
4.1.9.4.1 SNM solution in ENCLOS-3A18	SNM solution in ENCLOS-3A18 IE=-1	BUM-10(P) (-4) BUM-11(P) (-4)	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.9.4.2 SNM solution in ENCLOS-3B18	SNM solution in ENCLOS-3B18 IE=-1	BUM-6(P) (-4) BUM-12(P) (-4)	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3
4.1.10 SNM Backflow into nitrogen supply	Loss of supply pressure IE=-1 Motive backflow force EE=-1	BUM-8(P) (-4) BPF-19(A) (-2)	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
4.1.14 SNM Backflow into cooling supply	Loss of supply pressure IE=-1 Motive backflow force EE=-1	BUM-13(P) (-2) BUM-8(P) (-4)	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
4.1.15 FRNCOV-3A01/-3B01 Mass Limit Exceeded	Too much U in FRNCOV-3A01/-3B01 (BUM-2) (-2)	BUM-14(A) (-2) BPF-6 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.17 ENCLOS-3A18/-3B18 Container Limit Exceeded in Enclosure	Exceed container limit in ENCLOS-3A18/-3B18 (BUM-3) (-2)	BPF-6 (-2) BUM-14(A) (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.19 DISOLV-3A05/-3B05 Mass Limit Exceeded	Too much U in DISOLV-3A05/3A22 or DISOLV-3B05/3B22 (BUM-2) (-2)	BUM-14(A) (-2) BUM-1 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.20 Undissolved Uranium Transferred to Column 3C01-3C03	Valve BA-3A08A/-3B08A fails open IE=-1	BUM-1 (-2) BUM-15(P) (-3)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.21 SNM Backflow into DI Water system	Motive backflow force IE=-1 Loss of supply pressure EE=-1	BUM-8(P) (-4) BPF-20(A) (-2)	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.22.4.1 Exceed Safe Solution Depth in ENCLOS-3C08	SNM solution leak in enclosure IE=-1 operator failing to stop the leak EE=-1	BUM-17(P) (-4) BUM-18(P) (-4)	Unc T = -2 Con T = -10	Unc = 3 Con = 1	3 3	9 3
4.1.22.4.2 Exceed Safe Solution Depth in ENCLOS-3C08	SNM solution leak in enclosure (BUM-7) (-2) operator failing to stop the leak EE=-1	BUM-17(P) (-4) BUM-18(P) (-4)	Unc T = -3 Con T = -11	Unc = 2 Con = 1	3 3	6 3
4.1.22.4.3 Exceed Safe Solution Volume in ENCLOS-3C08 Bagout Port	SNM solution leak in enclosure IE=-1 operator failing to stop the leak EE=-1	BUM-7(P) (-2) BUM-19(P) (-3)	Unc T = -2 Con T = -7	Unc = 3 Con = 1	3 3	9 3
4.1.22.4.4 Exceed Safe Solution Volume in ENCLOS-3C08 Bagout Port	SNM solution leak in enclosure See IROFS No credit for duration operator failing to stop the leak EE=-1	BUM-7(P) (-2) BUM-19(P) (-3)	Unc T = -3 Con T = -6	Unc = 2 Con = 1	3 3	6 3
4.1.25 Dissolver/ Furnace Wall Thickness is Reduced	Exposure to a corrosive IE=0	BUM-20(P) (-4) BPF-5 (-2)	Unc T = 0 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.26.4.1 Container spacing upset with process equipment with only one operator handling portable containers	Container spacing upset with process equipment See IROFS as appropriate	BPF-5 (-2) Dur=0 BPF-4 (-2)	Unc T = -2 Con T = -4	Unc = 3 Con = 1	3 3	9 3
4.1.26.4.1.b Container spacing upset with process equipment with only one operator handling portable containers	Operator hand carries more than one container See IROFS as appropriate	BPF-4 (-2) Dur=0 BPF-5 (-2)	Unc T = -2 Con T = -4	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.26.4.2 Container spacing upset with storage racks with Two or More Operators Handling Portable Containers	Container spacing upset with process equipment from 1st operator (BPF-5) (-2)	Container spacing upset with process equipment from 2nd operator BPF-5 (-2)	Unc T = -2 Con T = -4	Unc = 3 Con = 1	3 3	9 3
4.1.28 Pump seal fails	Pump seal fails IE=0 Loss of supply pressure EE=-1	BPF-20(A) (-2) BUM-16 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.29 Pump seal fails	Pump seal fails IE=0 Loss of supply pressure EE=-1	BPF-21(A) (-2) BUM-4(A) (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
URANIUM METAL SAMPLING AREA						
Item BMS-39.1, Section 4.1.1, Too much U in ENCLOS-3E03	Exceed container limit in ENCLOS-3E03 $Frq_1 = -1$ Human error, trained operator fails to observe can in enclosure, adds additional can, defeats spacer barrier and enables full reflection.	BMS-1 -2 ENCLOS-3E03 -3 Enabled Full Reflection -3	Unc $T_1 = -1$ Con $T_1 = -9$	Unc = 3 Con = 1	3 3	9 3
Item BMS-39.1, Section 4.1.1, Too much U in ENCLOS-3E03	Exceed container limit in ENCLOS-3E03 See IROFS-BMS-1C or IROFS-BPF-3C as applicable[1]. IROFS Failure, Trained operator observes can in enclosure, adds two additional cans, removes spacer barrier and enables full reflection	BMS-1 -2 $Dur_2 = 0$ ENCLOS-3E03 -3 $Dur_3 = -3$ Enabled Full Reflection -3	Unc $T_2 = -2$ Con $T_2 = -8$ Unc $T_3 = -3$ Con $T_3 = -11$	Unc = 3 Con = 1 Unc = 2 Con = 1	3 3 3 3	9 3 6 3
UAL DISSOLUTION						
Backflow-1	Valve Failure or Rosemount System Failure IE = 1 Pressure Loss in Nitrogen System EE = 1 Operator fails to detect overflow and correct situation EE = 1	BPF-24 (P) -4 BPF-19 (A) -2	Unc T = -3 Con T = -9	Unc = 2 Con = 1	3 3	6 3

[1] For these sequences the initiating event is failure of one of the IROFS. Hence the frequency is assigned under the IROFS column.

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
Backflow-2	Pump Diaphragm leaks IE = -1/ Pressure Loss in Plant Air System EE = -1/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BPF-21 (A) -2	Unc T = -3 Con T = -9	Unc = 2 Con = 1	3 3	6 3
Backflow-3	Condenser, demister, or valve Failure IE = -1/ Pressure Loss in Nitric Acid System EE = -1/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BUA-1 (A) -2	Unc T = -3 Con T = -9	Unc = 2 Con = 1	3 3	6 3
Backflow-4	Valve, Pump, Flow-meter, N_2 line, condenser, demister, or Rosemount Failure IE = -1/ Pressure Loss in DI Water System EE = -1/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BPF-25 (A) -2	Unc T = -3 Con T = -9	Unc = 2 Con = 1	3 3	6 3
Backflow-5	Valve, N_2 line, condenser, demister, or Flow-meter Failure IE = -1/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BUA-2 (A) -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
Spill-1	Cooling water system, valve, demister, pump, flow-meter, condenser, heater, nitrogen supply, or Rosemount failure IE = -0/ Operator fails to detect spill and correct situation EE = -1	BPF-1 -2 BPF-2 -2	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
Spill-2A	Valve, dissolver, enclosure, process line, centrifuge, column, pump, flow-meter, condenser, or demister failures IE = -1/	BPF-1 -2 BPF-2 -2	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
Spill-2B	Valve, dissolver, enclosure, process line, centrifuge, column, pump, flow-meter, condenser, or demister failures IE = -1/ Container is in vicinity of leaking fissile material EE = -1/	BPF-1 -2 BPF-3 -2	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
Enclosure-1	Condenser tubes fail IE = -2/ Dissolver lid left open EE = -1/ Operator fails to detect overflow and correct situation EE = -1/	BUA-3 (P) -4 BUA-4 (P) -4	Unc T = -4 Con T = -12	Unc = 1 Con = 1	3 3	3 3
Enclosure-2A	*See IROFS*	*BUA-5 (A)* -2 Dur = 0 BUA-6 -2	*Unc T = -2* Con T = -4	Unc = 3 Con = 1	3 3	9 3
Enclosure-2B	See IROFS	BUA-6 -2 Dur = 0 BUA-5 (A) -2	Unc T = -2 Con T = -4	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
Enclosure-3	Operator fails to detect uranium metal container from shipping information IE = -1	BPF-8 -2 BUA-5 (A) -2 BUA-6 -2 BUA-7 -2	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3
CoolingWaterSupply-1	Dissolver Column Overflows IE = 0/ Operator fails to detect overflow and correct situation EE = -1/ Pressure Loss in Cooling Water Supply/Return line EE = -1	BPF-24 (P) -4 BUA-8 (P) -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
Centrifuge-1	Uranium solids exit the rotor and enter the unfavorable geometry region of the centrifuge IE = -1	BUA-9 (P) -4 BUA-10 (P) -4 BUA-11 -2	Unc T = -1 Con T = -11	Unc = 3 Con = 1	3 3	9 3
Filter Enclosure-1	Valve leak occurs spilling uranium solution into the filter enclosure IE = 0 Operator fails to detect and correct the valve leak EE = -1	BUA-12 (P) -4 BUA-13 (P) -4	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
HIGH SECURITY STORAGE AREA						
4.1.1.4.1 Container spacing upset with storage racks	Container spacing upset with storage racks BPF-5 (IE=-2)	RACKSBAS-8(P) (-4) BPF-4 -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
4.1.1.4.2 Container spacing upset with carts	Container spacing upset with carts BPF-5 (IE=-2)	CARTSBAS-9(P) (-4) BPF-4 -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
4.1.2 Too much material in containers placed on storage rack	Overloaded Container 10 kg over limit (IE=-2)	BPF-7 (-2) BPF-8 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.5 An oversized or wrong container is placed on the racks	An oversized or wrong container is placed on the racks See IROFS as appropriate	BAS-1 (-2) (Dur_1=-1) BAS-2 (-2) Dur_2=-1	Unc T=-2 Con T=-5	Unc = 3 Con = 1	3 3	9 3
4.1.5 An oversized or wrong container is placed on the racks	An oversized or wrong container is placed on the racks See IROFS as appropriate	BAS-2 (-2) (Dur=0) BAS-1 (-2)	Unc T=-2 Con T=-4	Unc=3 Con=1	3 3	9 3
4.1.8 Rack holder wall thickness is less than specified	Rack holder wall thickness is less than specified See IROFS as appropriate	BAS-3 (-2) (Dur=-1) BAS-4 (-2)	Unc T=-2 Con T=-5	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.8 Rack holder wall thickness is less than specified	Rack holder wall thickness is less than specified See IROFS as appropriate	BAS-4 (-2) (Dur=0) BAS-3 (-2)	Unc T = -2 Con T = -4	Unc = 3 Con = 1	3 3	9 3
4.1.9.4.1 Too many hand carried containers are moved in an aisle	Too many hand carried containers are moved in an aisle See IROFS as appropriate	BPF-4 (-2) (Dur = -1) BAS-5 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.9.4.1 Too many hand carried containers are moved in an aisle	Too many hand carried containers are moved in an aisle See IROFS as appropriate	BPF-5 (-2) (Dur=-1) BAS-4 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.9.4.2 Too many carts are moved in an aisle	Too carts are moved in an aisle See IROFS as appropriate	BAS-6 (-2) (Dur = -1) BAS-7 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.9.4.2 Too many carts are moved in an aisle	Too carts are moved in an aisle See IROFS as appropriate	BAS-7 (-2) (Dur=-1) BAS-6 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
SOLVENT EXTRACTION						
Backflow-1	Valve Failure or Rosemount System Failure IE = 0/ Pressure Loss in Nitrogen System EE = -1/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BPF-19 (A) -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
Backflow-2	Pump Diaphragm leaks IE = 0/ Pressure Loss in Plant Air System EE = -1/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BPF-21 (A) -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
Backflow-3	Valve Failure IE = 0/	BPF-24 (P) -4 BSX-1 (A) -2	Unc T = 0 Con T = -6	Unc = 3 Con = 1	3 3	9 3
Backflow-4	Valve, Pump, Condenser, or Column Overflow Failure IE = 0/ Pressure Loss in DI Water System EE = -1/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BPF-20 (A) -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
Backflow-5	Pump, Valve, Controller, or Flow Switch Failure IE = 0/ Operator fails to detect overflow and correct situation EE = -1	BPF-24 (P) -4 BSX-2 (A) -2	Unc T = -1 Con T = -7	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
Spill-1	Valve, Pump, Condenser, Flow Switch, Nitrogen Pressure, Plant Air, Rosemount System, or Controller Failures IE = 0/ Process Column Overflows EE = 0/ Knock-out Column Overflows EE = 0/ Operator fails to detect spill and correct situation EE = -1	BPF-1 -2 BPF-2 -2	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3
Spill-2A	Valve, Column, Process Line, or Strainer Failures IE = 0/ Operator fails to detect spill and correct situation EE = -1	BPF-1 -2 BPF-2 -2	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
Spill-2B	Valve, Column, Process Line, or Strainer Failures IE = 0/ Operator fails to detect spill and correct situation EE = -1	BPF-1 -2 BPF-3 -2	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
Drybox-1	Valve BA-2125 Fails IE = 0/ Filtrate Column Overflows EE = 0/ Operator fails to detect backflow and correct situation EE = -1/ Valve BA-2130 Fails EE = 0	BSX-3 (P) -4 BSX-4 (P) -4	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3
Drybox-2A	See IROFS	BSX-5 -2 Dur = 0 BSX-6 (P) -4	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
Drybox-2A	IROFS	BSX-5 -2 BSX-6 (P) -4 Dur = -3	Unc T = -4 Con T = -9	Unc = 1 Con = I	3 3	3 3
Drybox-2B	See IROFS	BSX-8 (P) -4 Dur = 0 BSX-7 (P) -4	Unc T = -4 Con T = -8	Unc = 1 Con = I	3 3	3 3
Drybox-2B	See IROFS	BSX-8 (P) -4 BSX-7 (P) -4 Dur = -3	Unc T = -4 Con T = -11	Unc = 1 Con = I	3 3	3 3
CoolingWaterSystem-1	Reflux Column Overflows IE = 0/ Operator fails to detect overflow and correct situation EE = -1/ Pressure Loss in Cooling Water Supply/Return line EE = -1	BPF-24 (P) -4 BSX-9 (P) -2	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
BuildingWalls-1	Process solution line leaks in region of piping penetration IE = -2	BSX-10 (P) -4	Unc T = -2 Con T = -6	Unc = 3 Con = I	3 3	9 3
DOWNBLENDING PROCESS AREA						
4.1.1.1 High Volume in the Staging Columns	Valve leak; level transmitter failure IE = -1 Operator fails to verify volume EE = -1	BDB-9 (-2) BDB-10 (-2)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.1.2 High Conc. in the Staging Columns	Density transmitter failure/ sampling error IE = -2	BDB-11 (-2) BDB-9 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.1.3 High Enrichment in the Staging Columns	Sampling error (-2)	BDB-1 (-2) BDB-10 (-2)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.1.4 Too little Blendstock in Blend Tank	Level check error/ tank leak IE = -2	BDB-12 (-2) BDB-13 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.1.5 Blend is Double Batched	Operator attempts to refill Staging Columns IE = -2 Operator fails to verify Blend Tank Empty EE = -2	BDB-14 (-2) BDB-10 (-2)	Unc T = -4 Con T = -8	Unc = 1 Con = 1	3 3	3 3
4.1.1.6 Evaporation in Blend Tank	Prolonged evaporation IE = -1	BDB-2 (-2) BDB-3 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.1.7A Precipitation in Blend Tank	Operator adds Oversize Container with Precipitating Agent to Blend Tank See IROFS as appropriate	BDB-4 (-2) Dur = -1 BDB-5 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.1.7B Precipitation in Blend Tank	Operator adds Oversize Container with Precipitating Agent to Blend Tank See IROFS as appropriate	BDB-5 (-2) Dur = -1 BDB-4 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.1.8 HEUN added to Blend Tank	PUMPAD-4B10 Fails on IE = -1	BDB-15 (-4) BDB-16 (-4)	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3
4.1.2.1 Column overflow	Valve failure, line plugged; operator fails to detect IE = -1	BPF-1 (-2) BPF-2 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.2.2 Column spill (Operator Intervention)	Column or line failure IE = -1	BPF-1 (-2) BPF-2 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.2.3 Column spill (Container in vicinity)	Column or line failure IE = -1 Container in vicinity EE = -1	BPF-1 (-2) BPF-3 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.3.1 Backflow to DI water	Valve failure IE = -1 Pressure Loss in DI Water System EE = -1 Operator fails to detect overflow and correct EE = -1	BPF-24 (-4) BPF-20 (-2)	Unc T = -3 Con T = -9	Unc = 2 Con = 1	3 3	6 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.3.2 Backflow to Nitrogen	Valve failure or Rosemount System Failure IE = -1 Pressure Loss in Nitrogen System EE = -1 Operator fails to detect overflow and correct EE = -1	BPF-24 (-4) BPF-19 (-2)	Unc T = -3 Con T = -9	Unc = 2 Con = 1	3 3	6 3
4.1.4.1 Evaporation in Hold Tank	Prolonged evaporation IE = -1	BDB-3 (-2) BDB-3 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.4.2A Precipitation in Hold Tank	Operator adds Oversize Container with Precipitating Agent to Hold Tank See IROFS as appropriate	BDB-4 (-2) Dur = -1 BDB-5 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.4.2B Precipitation in Hold Tank	Operator adds Oversize Container with Precipitating Agent to Hold Tank See IROFS as appropriate	BDB-5 (-2) Dur = -1 BDB-4 (-2)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3
LIQUID WASTE DISCARD SYSTEM						
Scenario A Sequence 12	Solution at >0.10 g/l ^{235}U delivered to columns (IE = -1)	BLW-2 (-2) BLW-4 (A) (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
Scenario A Sequence 15	>50 gram ^{235}U residual holdup in tank (IE = -2)	BLW-1 (-2) BLW-2 (-1)	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
Scenario A Sequence 16	>50 gram ^{235}U residual holdup in tank (IE = -2) Solution at >0.10 g/l ^{235}U delivered to columns (EE = -1)	BLW-1 (-2) BLW-2 (-1)	Unc T = -3 Con T = -6	Unc = 2 Con = 1	3 3	6 3
Scenario A Sequence 17	>50 gram ^{235}U residual holdup in tank (IE = -2)	BLW-1 (-2) BLW-2 (-2)	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
Scenario A Sequence 18	>50 gram ^{235}U residual holdup in tank (IE = -2) Solution at >0.10 g/l ^{235}U delivered to columns (EE = -1)	BLW-1 (-2) BLW-2 (-2)	Unc T = -3 Con T = -7	Unc = 2 Con = 1	3 3	6 3
Scenario A Sequence 21	>50 gram ^{235}U residual holdup in tank (IE = -2)	BLW-1 (-2) BLW-2 (-1) BLW-4 (A) (-2)	Unc T = -2 Con T = -7	Unc = 3 Con = 1	3 3	9 3
Scenario A Sequence 22	>50 gram ^{235}U residual holdup in tank (IE = -2) Solution at >0.10 g/l ^{235}U delivered to columns (EE = -1)	BLW-1 (-2) BLW-2 (-1) BLW-4 (A) (-2)	Unc T = -3 Con T = -8	Unc = 2 Con = 1	3 3	6 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
Scenario A Sequence 23	≥50 gram ^{235}U residual holdup in tank (IE = -2)	BLW-1 (-2) BLW-2 (-2) BLW-4 (A) (-2)	Unc T = -2 Con T = -8	Unc = 3 Con = 1	3 3	9 3
Scenario A Sequence 24	≥50 gram ^{235}U residual holdup in tank (IE = -2) Solution at >0.10 g/l ^{235}U delivered to columns (EE = -1)	BLW-1 (-2) BLW-2 (-2) BLW-4 (A) (-2)	Unc T = -3 Con T = -9	Unc = 2 Con = 1	3 3	6 3
Scenario B	Solution at >0.10 g/l ^{235}U delivered to columns (IE = -1)	BLW-2 (-2) BLW-3 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
PROCESS EXHAUST VENTILATION						
4.1.1 (a) HEPA Filter fails open	HEPA filter fails open Frq_{ii} = -2	BPV-1 -2 BPV-2 -2	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.1 (b) HEPA Filter fails open	HEPA filter and Differential Pressure Indicator fails Frq_{ii} = -2	BPV-2 -2 BPV-3 -2	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3

Accident Sequence	Initiating Events/ Enabling Events	IROFS Effectiveness of Protection Index	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Conseq. Category	Risk Index
4.1.1 (c) HEPA Filter fails open	HEPA filter and NDA Scan fails Frq_{il} = -2	BPV-1 -2 BPV-3 -2	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.2.1 Loss of Ventilation to Enclosures with misaligned ductwork valves	Misaligned Ductwork Valves Frq_{il} = -2	BPV-1 -2 BPV-2 -2	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.2.5 Loss of Ventilation to Enclosures with Blower Unit Failure	Blower Unit Failure Frq_{il} = -2	BPV-1 -2 BPV-2 -2	Unc T = -2 Con T = -6	Unc = 3 Con = 1	3 3	9 3
4.1.2.9 Loss of Ventilation to Enclosures with Blocked Scrubber Flow	Blocked Scrubber Flow Frq_{il} = -3	BPV-1 -2 BPV-2 -2	Unc T = -3 Con T = -7	Unc = 2 Con = 1	3 3	6 3
4.1.3 Uranium Accumulation in Ductwork	Process Column Overflow Frq = -1	BPV-4 -4 BPV-5 -4	Unc T = -1 Con T = -9	Unc = 3 Con = 1	3 3	9 3
4.1.4 Precipitation of Solids/Accumulation of Uranium in the Scrubber	Uranium enters ductwork and scrubber Frq_{il} = -1	BPV-2 -2 BPV-3 -2	Unc T = -1 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.5 Uranium Accumulation in the Blow down Tank	Uranium enters ductwork and scrubber Frq_{il} = -1	BPV-2 -2 BPV-3 -2	Unc T = -2 Con T = -5	Unc = 3 Con = 1	3 3	9 3
4.1.6 Inadvertent Discharge to Waste Water	Isolation Valve Failure Frq_{il} = -3	BPV-2 -2 BPV-3 -2	Unc T = -3 Con T = -7	Unc = 2 Con = 1	3 3	6 3

Table 4-10
Chemical Safety Risk Assessment

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
High Consequences													
Evaluation 1: U-Metal Dissolution (See Utilities UTD40.17A for nitric acid line breach 1UMD1.4, 2UMD2.4)													
1UMD1.7 2UMD2.7	Column 3A11 overfills Column 3B11 overfills		Human error For Mechanical failure see IROFS failure 1UMD1.139 and 2UMD2.139 below	1			2	3	U U	1 6	3 1	3 3	9 3
IROFS failure 1UMD1.139 2UMD2.139	Spring Return Valve BA-3A25 or BA-3B25 fail open		Human error Mechanical failure				2 dur=4	3	U U	2 9	3 1	3 3	9 3
IROFS failure	BUM-22 Operator fails to shut upstream isolation valve BA-3A73/3B73 upon completion of fill operation		Human error Mechanical failure				3 dur=2	2	U U	3 7	2 1	3 3	6 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
Evaluation 3: U-Natural Dissolution													
UND6.39	Valve HV-4D04A fails open		Human error	1			2	2	U G	[illegible]	3 1	[illegible]	9 3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index U	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	0			12	12	100	0	3	3	3

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Valve PL-4D25 fails to manually close upon level gauge LG-4D04 high level		Human error Mechanical failure				2 dur=4	2	U C	2 8	3 1	3 3	9 3
IROFS failure	• HV-7B01B does not shut upon liquid detection at level switch LSHH-4D14A • Tank 4D04 overflow COLUMN-4D14 does not hold residual nitric acid volume upon shutting HV-7B01B • LSSH-4D14A fails to indicate high level in Tank 4D04 overflow therefore, not removing power from HV-7B01B		Human error Mechanical failure				2 dur=4	2	U C	2 8	3 1	3 3	9 3
IROFS failure	Valve PL-4D25 fails to manually close upon level gauge LG-4D04 high level		Human error Mechanical failure				2 dur=4	2	U C	2 8	3 1	3 3	9 3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
IROFS failure	HV-7B01B does not shut upon loss of power to Level Switch LSSH-4D14A or HV-7B01B		Human error Mechanical failure				2 dur=0	2	U	2	3	3	9
IROFS failure	Valve PL-4D25 fails to manually close upon level gauge LG-4D04 high level		Human error Mechanical failure				2 dur=4	2	U	2	3	3	9
IROFS failure	Valve BA-4D88 is open during Tank 4D04 fill or batch adjust with bulk nitric acid		Human error Mechanical failure				2 dur=0	2	U	2	3	3	9
UND6.41	Flow Totalizer FT-4D04A fails (low flow)		Human error	1			2	2	U	1	3	3	9

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	0	BUND-1 Administrative Control, (Manual closure of Valve PL-4D25 upon level gauge LG-4D04 high level		2	2	UC	0 4	3 1	3 3	9 3
UND6.43	Nitric acid supply line breaks		Human error	1			2	2	UC	1 5	3 1	3 3	9 3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	1			3	2	U C	1 6	3 1	3 3	9 3
			Impact accident	1			3	3	U C	1 7	3 1	3 3	9 3
Evaluation 7 Vapor Loss (NOx) from Tank 4D04													
UND6.29I	NOx is generated		Heating of nitric acid in a large tank with a large surface area	0			3	2	U C	0 3	3 1	3 3	9 3
IROFS failure	NOx Detection and Alarm System fails to detect or alarm		Human error Mechanical Failure				2 dur=0	2	U C	2 4	3 1	3 3	9 3

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Local TANK-4D04 WOG/POG ventilation is lost but Loss of Ventilation alarm does not alarm		Human error Mechanical Failure Cause for Loss of Ventilation PS45.31 SCRUBR-6H02 Demister plugs PS45.32 SCRUBR-6H02 Demister fails open PS45.34 SCRUBR-6H02Tray plugs PS45.38 Valve DA-6H32 fails closed PS45.40 BLOWER-6H06 fails off PS45.41 BLOWER-6H06 fails in reverse direction PS45.52 Valve BF-6H55 fails closed PS45.111 Valve DA-				2 dur=0	2	U O	2 L	3 1	3 3	9 3

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			6H54 fails closed PV44.3 Balance of plant ventilation butterfly/ damper valves misaligned PV44.11 Valve SG-6G50 fails closed PV44.20 Valve BF-6G84 fails closed										
IROFS failure UND6.224	BUND.10 Tank 4D04 POG Line breaches		Human error Mechanical failure Impact accident	1			2	2	U	1	3	3	3
IROFS failure UND6.223	BUND.10 TANK 4D04 Tank POG Line plugs		Foreign Material	2			2	2	U	2	3	3	3
Evaluation 1/ Solvent Extraction Feed Column (See Utilities UTD40.17A for nitric acid line breach SXFC9.15)													
IROFS failure SXFC9.5	BSX.1 Spring Return Valve BA-2A25 fails open (fails to shut upon operator release) Upstream valve BA-2A26 is normally shut when not filling		Human error Mechanical failure				2 dur=4	2	U	2	3	3	3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	BSX-33 Operator fails to shut upstream isolation valve BA-2A26 upon completion of fill operation		Human error Mechanical failure				2 dur=2	2	U C	2 6	3 1	3 3	9 3
Evaluation 1: First Pass Solvent Evaporator (See Utilities UTD40.17A for nitric acid line breach 1PE12.47)													
1PE12.43	Valve BA-2052 fails open		Human error	1			2	2	U C	1 5	3 1	3 3	9 3
			Mechanical failure	0			2	2	U C	0 4	3 3	3 3	9 3
IROFS failure 1PE12.45	Spring Return Valve BA-2053 fails open (fails to shut upon operator release)]		Human error Mechanical failure				2 dur=4	3	U C	2 9	3 1	3 3	9 3
IROFS failure	BA-2052 discharge is not capped when not in use		Human error Mechanical failure				3 dur=2	2	U C	3 7	2 1	3 3	6 3
IROFS failure 1PE12.45	Spring Return Valve BA-2053 fails open (fails to shut upon operator release)] Upstream valve BA-2091 is normally shut when not filling or sampling		Human error Mechanical failure				2 dur=4	2	U C	2 8	3 1	3 3	9 3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	BSX-33 Operator fails to shut upstream isolation valve BA-2091 upon completion of fill operation		Human error Mechanical failure				2 dur=2	2	U C	2 5	3 1	3 3	9 3
Evaluation 1, First Pass Raffinate Storage (See Utilities UTD40.17A for nitric acid line breach 1PRS17.21)													
1PRS17.18A	Valve TW2G40 misaligned (When Sampling)		Human error	1			2	2	U C	1 5	3 1	3 3	9 3
			Mechanical failure	0			2	2	U C	0 4	3 1	3 3	9 3
IROFS failure	Spring Return Valve BA-2G39 fails open (fails to shut upon operator release)		Human error Mechanical failure				2 dur=4	3	U C	2 9	3 1	3 3	9 3
IROFS failure	TW-2G40 discharge is not capped when not in use		Human error Mechanical failure				3 dur=2	2	U C	3 7	2 1	3 3	6 3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
1PRS17.18B	Valve TW2G40 misaligned (When filling)		Human error	1			2	2	U G	1 5	3 1	3 3	9 3
			Mechanical failure	0			2	2	U G	0 4	3 1	3 3	9 3
IROFS failure	Spring Return Valve BA-2G39 fails open (fails to shut upon operator release) Downstream valve BA-2G41 is normally shut when not filling		Human error Mechanical failure				2 dur=4	2	U G	2 8	3 1	3 3	9 3
IROFS failure	Operator fails to shut downstream isolation valve BA-2G41 upon completion of fill operation		Human error Mechanical failure				2 dur=2	2	U G	2 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
Evaluation 2, Second Pass Raffinate Storage (See Utilities UTD40.17A for nitric acid line breach 2PRS18.8)													
IROFS failure 2PRS18.4	BSX-1 Spring Return Valve BA-2H33 fails open (fails to shut upon operator release) Upstream valve BA-2H34 is normally shut when not filling		Human error Mechanical failure				2 dur=4	2	U C	2 8	3 1	3 3	9 3
IROFS failure	BSX-33 Operator fails to shut upstream isolation valve BA-2H34 upon completion of fill operation		Human error Mechanical failure				2 dur=2	2	U C	2 6	3 1	3 3	9 3
Evaluation 1, Solvent Extraction Sump Columns (See Utilities UTD40.17A for nitric acid line breach SXSG19.8)													
IROFS failure SXSG19.3	BSX-1 Spring Return Valve BA-2J30 fails open (fails to shut upon operator release) Upstream valve BA-2J35 is normally shut when not filling		Human error Mechanical failure				2 dur=4	2	U C	2 8	3 1	3 3	9 3
IROFS failure	BSX-33 Operator fails to shut upstream isolation valve BA-2J35 upon completion of fill operation		Human error Mechanical failure				2 dur=2	2	U C	2 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative / Preventive IROFS$_2$ and IROFS failure	IROFS$_1$ Effectiveness of Protection Index	IROFS$_2$ Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Evaluation 1: Solvent Extraction Chemical Sheet 1 (See Utilities UTD40.17A for nitric acid line breach 1SXCM23.6)													
IROFS failure 1SXCM23.4	BSX-1 Spring Return Valve BA-2L45 fails open (fails to shut upon operator release)		Human error				2 dur=4	2	U	2 8	3 1	3 3	9 3
IROFS failure	BSX-33 Operator fails to shut upstream isolation valve BA-XXXX upon completion of fill operation		Mechanical failure				2 dur=0	2	U G	2 4	3 1	3 3	9 3
Evaluation 6: 1: U-Aluminum Separation (See Utilities UTD40.17A for nitric acid line breach 1UALS33.55)													
IROFS failure 1UALS33.98	BUA-1 Spring Return Valve BA-1E52 fails open (fails to shut upon operator release)		Human error				2 dur=4	2	U	2 8	3 1	3 3	9 3
IROFS failure	BUA-14 Operator fails to shut upstream isolation valve BA-1E29 upon completion of fill operation		Mechanical failure				2 dur=0	2	U G	2 4	3 1	3 3	9 3
Evaluation 6: 2: U-Aluminum Separation (See Utilities UTD40.17A for nitric acid line breach 2UALS34.52)													
IROFS failure 2UALS34.91	BUA-1 Spring Return Valve BA-1F52 fails open (fails to shut upon operator release)		Human error Mechanical failure				2 dur=4	2	U	2 8	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	BUA-14 Operator fails to shut upstream isolation valve BA-1F29 upon completion of fill operation		Human error Mechanical failure				2 dual-0	2	U C	2 4	3 1	3 3	9 3
Evaluation 5: Utilities; Evaluation 1: U-Metal Dissolution													
UTD40.17A 1UMD1.4 2UMD2.4 SXFC9.15 1PE12.47 1PRS17.21 2PRS18.8 SXSC19.8 1SXCM23.6 1UALS33.55 2UALS34.52	Nitric acid supply line breaks		Human error	1			2	2	U C	5 5	3 1	3 3	9 3
			Mechanical failure	1			3	2	U C	6 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS$_1$ Effectiveness of Protection Index	IROFS$_2$ Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Impact accident	1			3	3	U	1	3	3	9
UTD40:17B	Nitric acid line breaks		Human error	1			2	2	U	1	3	3	9
			Mechanical failure	1			2	3	U	1	3	3	9
			Impact accident	1			2	3	U	1	3	3	9

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Impact accident	[illegible]			[illegible]	[illegible]	U C	[illegible]	3 1	3 3	9 3
IROFS failure	Independent verification is not performed or performed incorrectly so that system is not isolated or drained prior to maintenance		Human error				[illegible] dur=0	[illegible]	U C	[illegible]	3 1	3 3	9 3
IROFS failure	Independent verification is not performed or performed incorrectly so that maintenance is performed incorrectly or system is incorrectly restored upon completion of maintenance		Human error				[illegible] dur=0	[illegible]	U C	[illegible]	3 1	3 3	9 3
IROFS failure	Bulk chemical checks are not performed on an interval not to exceed quarterly		Human error				[illegible] dur=0	[illegible]	U C	[illegible]	3 1	3 3	9 3
IROFS failure	Outside bulk chemical lines are not stainless steel piping with welded connections		Mechanical failure				[illegible] dur=0	[illegible]	U C	[illegible]	2 1	3 3	6 3

Item	What if...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Motorized vehicle procedures and training fail to prevent operator impact accident		Impact accident				2 dur=4	3	U C	2 9	3 1	3 3	9 3
IROFS failure	Outside nitric acid lines are not elevated or if elevated are not located in a pipe chase with a vehicular barrier installed		Impact accident				3 dur=0	2	U C	3 5	2 1	3 3	6 3
IROFS failure	Motorized vehicle procedures and training fail to prevent operator impact accident		Impact accident				2 dur=4	2	U C	2 8	3 1	3 3	9 3
IROFS failure	If vehicle access is required inside the barrier a spotter is not used to direct vehicle movement		Impact accident				2 dur=3	2	U C	2 7	3 1	3 3	9 3
Scenario 8; Process Scrubber													
IROFS failure PS45:118	BPV-8 Operator fails to shut upstream isolation valve BA-6H74 upon completion of nitric acid fill operations		Human error Mechanical failure				2 dur=2	2	U C	2 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	BPV-7 Spring Return Valve BA-XXXX fails open (fails to shut upon operator release) Upstream valve BA-6H88 is normally shut when not filling		Human error Mechanical failure				2 dur-4	2	U C	2 8	3 1	3 3	9 3
IROFS failure PS45.118	BPV-9 Operator fails to shut upstream isolation valve BA-6H88 upon completion of nitric acid fill operations		Human error Mechanical failure				2 dur-2	2	U C	2 6	3 1	3 3	9 3
IROFS failure	BPV-10 Valve BA-6H88 discharge is not capped when not in use		Human error Mechanical failure				2 dur-0	2	U C	2 4	3 1	3 3	9 3
Red Oil Explosion, See Fire Safety Risk Assessment First Pass Extraction Evaluation 4, 1PX10.2, 1PX10.55, 1PX10.57, 1PX10.63 First Pass Evaporator Evaluation 8 1PE12.88, 1PE12.90, 1PE12.92, 1PE12.185, 1PE12.186, 1PE12.187 Second Pass Extraction Evaluation 4 2PSX13.35, 2PSX13.37, 2PSX13.41, 2PSX13.71, 2PSX13.90 Second Pass Evaporator Evaluation 8 2PE15.82, 2PE15.84, 2PE15.86, 2PE15.155, 2PE15.156, 2PE15.157													
Scenario 8, Hydrogen, See Fire Safety Risk Assessment 1UALD29.45, 1UALD29.48, 1UALD29.49, 1UALD29.66, 1UALD29.70, 1UALD29.84 2UALD30.45, 2UALD30.48, 2UALD30.49, 2UALD30.66, 2UALD30.70, 2UALD30.84 3UALD31.45, 3UALD31.48, 3UALD31.49, 3UALD31.66, 3UALD31.70, 3UALD31.84 4UALD32.45, 4UALD32.48, 4UALD32.49, 4UALD32.66, 4UALD32.70, 4UALD32.84													

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 7, Hydrogen, See Fire Safety Risk Assessment 1UALD29.23, 1UALD29.25, 1UALD29.26, 1UALD29.30, 1UALD29.78, 1UALD29.80, 1UALD29.88 2UALD30.23, 2UALD30.25, 2UALD30.26, 2UALD30.30, 2UALD30.78, 2UALD30.80, 2UALD30.88 3UALD31.23, 3UALD31.25, 3UALD31.26, 3UALD31.30, 3UALD31.78, 3UALD31.80, 3UALD31.88 4UALD32.23, 4UALD32.25, 4UALD32.26, 4UALD32.30, 4UALD32.78, 4UALD32.80, 4UALD32.88													
Intermediate Consequences													
Evaluation 1, Caustic Makeup and Storage Tanks													
CMST38.1	Valve HV-1K02A fails open		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	0			3	N/A	U	0	3	2	6
CMST38.30	Level Switch LSHH-1K02 fails low		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	0			3	N/A	U	0	3	2	6
Scenario 3 Caustic Makeup and Storage Tanks													
CMST38.5	NaNO2 Tank 1K01 breaches		Human error	1			3	N/A	U	1	3	2	6

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	1			3	N/A	U G	1 4	3 1	2 2	6 2
			Impact Accident	1			3	N/A	U G	1 4	3 1	2 2	6 2
Scenario 4 Caustic Makeup and Storage Tanks													
CMST38.6	NaOH Tank TK02 breaches		Human error	1			3	N/A	U G	1 4	3 1	2 2	6 2
			Mechanical failure	1			3	N/A	U G	1 4	3 1	2 2	6 2

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Impact Accident	1			3	N/A	U C	1 4	3 1	2 2	6 2
Scenario 5 Caustic Makeup and Storage Tanks													
CMST38.28	Level Switche LSHH-1K01 fails low		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
CMST38.39	Operator is not present or becomes incapacitated		Emergency evacuation	0			3	N/A	U C	1 3	3 2	2 2	6 4
				0			3	N/A	U C	1 3	3 2	2 2	6 4
CMST38.51	$NaNO_3$ Tank 1K01 overfills from Sodium Nitrate Tanker		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 13 Caustic Makeup and Storage Tanks													
CMST38.25	Sodium Hydroxide NaOH line breaks		Human error	1			2	2	U	1	3	2	6
			Mechanical failure	1			3	N/A	U	1	3	2	6
			Impact accident	1			3	N/A	U	1	3	2	6

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 14 Caustic Makeup and Storage Tanks													
CMST38.26	Sodium Nitrate $NaNO_3$ line breaks		Human error	1			2	2	U G	1 5	3 1	2 2	6 2
			Mechanical failure	1			3	N/A	U G	1 4	3 1	2 2	6 2
			Impact accident	1			3	N/A	U G	1 4	3 1	2 2	6 2

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 15 Caustic Makeup and Storage Tanks													
CMST38.52	Sodium Nitrate $NaNO_3$ Tanker breaches		Human error	1			2	N/A	U	1	3	2	6
			Mechanical failure	1			2	N/A	U	1	3	2	6
			Impact accident	1			2	1	U	1	3	2	6
Scenario 2 Liquid Waste Discard													
CD27.26	Tank HV-5B01 POG plugs upstream of siphon break		Foreign material	1			3	N/A	U	1	3	2	6

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 4 Liquid Waste Discard													
CD27.21	Level Switch LSHH-5B01 fails low		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
Scenario 10 Liquid Waste Discard													
CD27.1	NaOH Tank 5B01 fails (breach)		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Impact accident	1			3	N/A	U C	1 4	3 1	2 2	6 2

Item	What If?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 4: Process Scrubber													
IROFS failure PS45.120	BPV-12 Operator fails to shut upstream isolation valve BA-6H98 upon completion of caustic operations		Human error Mechanical failure				2 dur=2	2	U C	2 6	3 1	2 2	6 2
IROFS failure	BPV-1311 Valve BA-6H98 discharge is not capped when not in use		Human error Mechanical failure				2 dur=0	2	U C	2 4	3 1	2 2	6 2
PS45.132	Valve 6H10A fails open		Human error	1			3	N/A	U C	5 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
PS45.134	NaOH Tank 6H10 fails (breach)		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	1			3	N/A	U	1	3	2	6
			Impact accident	1			3	N/A	U	1	3	2	6
Chemical Toxicity													
Scenario 34, Red Oil Red Oil Explosion; See Fire Safety Risk Assessment 1PX10.2, 1PX10.55, 1PX10.57, 1PX10.63, 2PSX13.35, 2PSX13.37, 2PSX13.41, 2PSX13.71, 2PSX13.90, 1PE12.88, 1PE12.90, 1PE12.92, 1PE12.185, 1PE12.186, 1PE12.187, 2PE15.82, 2PE15.84, 2PE15.86, 2PE15.155, 2PE15.156, 2PE15.157													
High Consequences													
Scenario 28, Rupture of U-Natural Tanker													

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
UNT7.3	Valve BA-4E34 fails open		Human error	1			3	2	U	6	3	3	3
			Mechanical failure	0			3	2	U	5	3	3	3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Natural Tanker Rupture Disc fails to rupture when pressure reaches 35 psig		Mechanical failure Human error				3 durat 0	2	U	3	2 1	3	6
UNT7.53 IROFS failure	Tanker POG line is plugged or not connected to Natural Tanker and Valve BA-4E42 is not open during filling operations and/or not constructed of stainless steel with a polypropylene steel wire helix		Human error Foreign Material				2 durat 3	3	U	2	2 1	3	9
Scenario 9; Employee Exposure; POG line breach while filling tanker													
IROFS failure UNT7.54	Natural Tanker POG Line breaches during filling operations		Human error Mechanical failure Impact Accident				2 durat 4	3	U	2	3 1	3	9

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Failure of BUND-8 Tanker fill line does not extend to bottom of Tanker allowing a waterfall effect when filling		Human error Mechanical failure Impact Accident				3 dur=0	2	U C	3 5	2 1	3 3	6 3

Table 4-11
Radiological Safety Risk Assessment – Worker

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
High Consequence													
Scenario number 8, Red Oil Explosion, See Fire Safety Risk Assessment 1PX10.2, 1PX10.55, 1PX10.57, 1PX10.63, 2PSX13.35, 2PSX13.37, 2PSX13.41, 2PSX13.71, 2PSX13.90, 1PE12.88, 1PE12.90, 1PE12.92, 1PE12.185, 1PE12.186, 1PE12.187, 2PE15.82, 2PE15.84, 2PE15.86, 2PE15.155, 2PE15.156, 2PE15.157													

Table 4-12
Environmental Chemical Risk Assessment

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative / Preventive IROFS and IROFS failure	IROFS Effectiveness of Protection Index	IROFS Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
High Consequence													
Scenario 3: Spill of 67% Nitric Acid (Inside BLDG 333)													
UND639	Valve HV-4D04A fails open		Human error	1			2	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	0			2	3	UC	0	3	3	9
IROFS failure	HV-7B01B does not shut upon liquid detection at level switch LSHH-4D14A Tank 4D04 overflow COLUMN-4D14 does not hold residual nitric acid volume upon shutting HV-7B01B LSSH-4D14A fails to indicate high level in Tank 4D04 overflow (therefore) not removing power from HV-7B01B		Human error Mechanical failure				2 dur-4	3	UC	2	1	3	9

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	LEU Area Dike fails to contain solution volume		Human error Mechanical failure				3 dur=0	2	U G	3 5	2 1	3 3	6 3
IROFS failure	HV-7B01B does not shut upon loss of power to Level Switch LSSH-4D14A or HV-7B01B		Human error Mechanical failure				2 dur=4	3	U G	2 9	3 1	3 3	9 3
IROFS failure	LEU Area Dike fails to contain solution volume		Human error Mechanical failure				3 dur=0	2	U G	3 5	2 1	3 3	6 3
IROFS failure	Valve BA-4D88 is open during Tank 4D04 fill or batch adjust with bulk nitric acid		Human error Mechanical failure				2 dur=0	3	U G	2 5	3 1	3 3	9 3
IROFS failure	LEU Area Dike fails to contain solution volume		Human error Mechanical failure				3 dur=0	2	U G	3 5	2 1	3 3	6 3

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
UND6.43	Nitric acid line breaks		Human error	1			2	3	U G	1 6	3 1	3 3	9 3
			Mechanical failure	1			2	3	U G	1 6	3 1	3 3	9 3
			Impact accident	1			2	3	U G	1 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Utility valve HV-7B01B fails to close upon nitric acid volume delivery		Human error Mechanical failure Impact accident				2 dur=1	3	U C	2 6	3 1	3 3	9 3
IROFS failure	LEU Area Dike fails to contain solution volume		Human error Mechanical failure Impact accident				3 dur=0	2	U C	3 5	2 1	3 3	6 3
Utilities Nitric Acid Line Break (Outside BLDG 333)													
UTD40.17B	Nitric acid line breaks		Human error	1			2	2	U C	1 3	3 1	3 3	9 3
			Mechanical failure	1			2	3	U C	1 6	3 1	3 3	9 3

Item	What If?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Impact accident	1			2	3	U	1	3	3	9
			Impact accident	1			2	2	U	1	3	3	9
IROFS failure	Independent verification is not performed or performed incorrectly so that system is not isolated or drained prior to maintenance		Human error				2 dur=0	2	U	2	3	3	9
IROFS failure	Independent verification is not performed or performed incorrectly so that maintenance is performed incorrectly or system is incorrectly restored upon completion of maintenance		Human error				2 dur=0	2	U	2	3	3	9

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Bulk chemical checks are not performed on an interval not to exceed quarterly		Human error				2 dur=0	3	U	2.5	3	3	9
IROFS failure	Outside bulk chemical lines are not stainless steel piping with welded connections		Mechanical failure				3 dur=0	2	U	3.5	2	3	6
IROFS failure	Motorized vehicle procedures and training fail to prevent operator impact accident		Impact accident				2 dur=4	3	U	2.9	3	3	9
IROFS failure	Outside nitric acid lines are not elevated or if elevated are not located in a pipe chase with a vehicular barrier installed		Impact accident				3 dur=0	2	U	3.5	2	3	6
IROFS failure	Motorized vehicle procedures and training fail to prevent operator impact accident		Impact accident				2 dur=4	2	U	2.8	3	3	9
IROFS failure	If vehicle access is required inside the barrier a spotter is not used to direct vehicle movement		Impact accident				2 dur=3	2	U	2.7	3	3	9

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 29, DI Water Overflow of Tank in Downblending Area													
UND6.46	Valve HV-4D04B fails open		Human error	1			2	3	U	1.6	3	3	9
			Mechanical failure	0			2	3	U	0.5	3	3	9
IROFS failure	Valve PL-4D26 fails to manually close upon level gauge LG-4D04 high level		Human error Mechanical failure				2 dur=24	3	U	2.9	3	3	9
IROFS failure	LEU Area Dike fails to contain solution volume		Human error Mechanical failure				3 dur=0	2	U	3.5	2	3	6
Scenario 8, Hydrogen, See Fire Safety Risk Assessment 1UALD29.45, 1UALD29.48, 1UALD29.49, 1UALD29.57, 1UALD29.59, 1UALD29.66, 1UALD29.70 2UALD30.45, 2UALD30.48, 2UALD30.49, 2UALD30.57, 2UALD30.59, 2UALD30.66, 2UALD30.70 3UALD31.45, 3UALD31.48, 3UALD31.49, 3UALD31.57, 3UALD31.59, 3UALD31.66, 3UALD31.70 4UALD32.45, 4UALD32.48, 4UALD32.49, 4UALD32.57, 4UALD32.59, 4UALD32.66, 4UALD32.70													

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 27.1 U-Aluminum Glovebox Enclosure Explosion; See Fire Safety Risk Assessment 1UALD29.45, 1UALD29.48, 1UALD29.49, 1UALD29.66, 1UALD29.70, 1UALD29.84 2UALD30.45, 2UALD30.48, 2UALD30.49, 2UALD30.66, 2UALD30.70, 2UALD30.84 3UALD31.45, 3UALD31.48, 3UALD31.49, 3UALD31.66, 3UALD31.70, 3UALD31.84 4UALD32.45, 4UALD32.48, 4UALD32.49, 4UALD32.66, 4UALD32.70, 4UALD32.84													
Intermediate Consequence													
Scenario 12, U-Aluminum Dissolution													
CMST38.52	Sodium Nitrate NaNO3 Tanker breaches		Human error	1			2	N/A	U G	1 3	3 2	2 2	6 4
			Mechanical failure	1			2	N/A	U G	1 3	3 2	2 2	6 4
			Impact accident	1			2	1	U G	1 4	3 1	2 2	6 2

Table 4-13
Environmental Radiological Risk Assessment

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
High Consequences													
Solvent Extraction													
Scenario number 8, Red Oil Explosion, See Fire Safety Risk Assessment 1PX10.2, 1PX10.55, 1PX10.57, 1PX10.63, 2PSX13.35, 2PSX13.37, 2PSX13.41, 2PSX13.71, 2PSX13.90, 1PE12.88, 1PE12.90, 1PE12.92, 1PE12.185, 1PE12.186, 1PE12.187, 2PE15.82, 2PE15.84, 2PE15.86, 2PE15.155, 2PE15.156, 2PE15.157													
U-Aluminum													
Scenario 9, Hydrogen, See Fire Safety Risk Assessment 1UALD29.45, 1UALD29.48, 1UALD29.49, 1UALD29.66, 1UALD29.70, 1UALD29.84 2UALD30.45, 2UALD30.48, 2UALD30.49, 2UALD30.66, 2UALD30.70, 2UALD30.84 3UALD31.45, 3UALD31.48, 3UALD31.49, 3UALD31.66, 3UALD31.70, 3UALD31.84 4UALD32.45, 4UALD32.48, 4UALD32.49, 4UALD32.66, 4UALD32.70, 4UALD32.84													
Intermediate Consequences													
Downblending													
Scenario 2, Indoor LEUN Solution Spill Scenario													
UDB5.78	MIXER-4C03 shaft or blade breaks		Human error	1			3	N/A	U	1	3	2	6

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	1			3	N/A	U	1	3	2	6
UDB5.83	Level gauge LG-4C01 leaks or breaks		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	1			3	N/A	U	1	3	2	6
			Impact accident	0			3	N/A	U	0	3	2	6
UDB5.84	TANK-4C01 leaks or breaks		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	1			3	N/A	U	1	3	2	6
			Impact accident	1			3	N/A	U	1	3	2	6
UDB5.91	Valve PL-4C29 fails open		Human error	1			3	N/A	U	1	3	2	6

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
UDB5.93	Valve BA-4C30/4C31 fails open		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
UDB5.97	TANK 4C01 recycle line breaks/leaks		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Impact accident	1			3	N/A	U C	1 4	3 1	2 2	6 2

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index I	Likelihood Category	Consequence Category	Risk Index
UDB5:100	Flex Line PB-4C02/4C03 leaks or breaks		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Impact accident	1			3	N/A	U C	1 4	3 1	2 2	6 2
UDB5:103	Valve PL-4C34 fails open		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
UDB5.138	POG Line Plugs (Blend Tank side of siphon break)		Foreign material in line	2			3	N/A	UC	2.5	3.1	2.2	6.2
UNT7.8	Valve HV-4E01B fails open		Human error	1			3	N/A	UC	1.4	3.1	2.2	6.2
			Mechanical failure	0			3	N/A	UC	0.3	3.2	2.2	6.4
UNT7.12	Level Transmitter LIT-4E01 fails low		Human error	1			3	N/A	UC	1.4	3.1	2.2	6.2
			Mechanical failure	0			3	N/A	UC	0.3	3.2	2.2	6.4
UNT7.13	Tank 4E01 leaks/breaks		Human error	1			3	N/A	UC	1.4	3.1	2.2	6.2

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	1			3	N/A	U	1	3	2	6
			Impact accident	1			3	N/A	U	1	3	2	6
UNT7.17	Valve PL-4E25 fails open		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	0			3	N/A	U	0	3	2	6
UNT7.19	Valve BA-4E26 fails open		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	0			3	N/A	U	0	3	2	6
UNT7.22	POG line plugs (upstream of siphon break) 333-F0552-D		Foreign material	2			3	N/A	U	2	3	2	6

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS Effectiveness of Protection Index	IROFS Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
Scenario 4: Indoor LEUN Solution Water Overfill/Spill Scenario													
UDB5.80	Level switch LIT-4C01A or LI-4C01A fails low (reads lower than actually exists)		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
UDB5.88	Level switch LSH-4C01B fails low (tank is full reads empty)		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
UDB5.116	Valve HV-4C01A fails open		Human error	1			3	N/A	U C	1 3	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	5 4
UDB5.129	Operator is absent or becomes incapacitated		Emergency evacuation	0			3	N/A	U C	0 3	3 2	2 2	5 4
UNT7.5	Valve BA-4E32 fails open		Human error	1			3	N/A	U C	1 3	3 1	2 2	6 2

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
UNT7.45	Operator not present or becomes incapacitated 333-F0552-D		Emergency evacuation	0			3	N/A	U C	0 3	3 2	2 2	6 4
Scenario 6: Outdoor UEUN Solution Spill Scenario													
UNT7.38A	UNB Transfer line breaks (underground)		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Impact accident	1			3	N/A	U C	1 4	3 1	2 2	6 2

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
UNT738B	UNB Transfer line breaks (above ground)		Human error	1			2	2	UC	5	1	2	2
			Mechanical failure	1			3	N/A	UC	4	1	2	2
			Impact accident	1			3	N/A	UC	4	1	2	2

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Impact accident	1			2	N/A	U	3	3	2	6
Scenario 10, Outdoor Natural UN Solution Spill													
UNT7.3	Valve BA-4E34 fails open		Human error	1			3	N/A	U	1	3	2	5
			Mechanical failure	0			3	N/A	U	0	3	2	5

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative / Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
UNI-731	Valve HV-4D06 fails open		Human error	1			2	2	U	7	3	2	6
			Mechanical failure	0			2	2	U	0	3	2	6
IROFS failure	Isolation Valve BA-4E41 fails open when U Natural transfer to Natural tanker operations are not in progress		Human error Mechanical failure				2 during	2	U	2	3	2	6
IROFS failure	Isolation Valve PL-4D66 fails open when U Natural transfer to Natural tanker operations are not in progress		Human error Mechanical failure				2 during	2	U	2	3	2	6

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
UNT7.37	Natural Tanker Input Line breaks		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	1			3	N/A	U	1	3	2	6
			Impact accident	1			3	N/A	U	1	3	2	6
UNT7.39	Natural Tanker leaks		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	1			2	N/A	U	1	3	2	6

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
			Impact accident	1			2	1	U	4	1	2	2
UNT7.42	Natural Tanker hose not connected		Human error	0			3	N/A	U	3	2	2	4
			Mechanical failure	1			3	N/A	U	4	1	2	2
UNT7.44	Natural Tanker impacts with surrounding property/equipment		Human error	1			2	1	U	4	1	2	2

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	1			2	1	U	1	3	2	6
UNT7.45	Operator not present or becomes incapacitated 333-F0554-D		Emergency evacuation	0			3	N/A	U	0	3	2	6
UNT7.53	Natural Tanker POG Line Plugs IROFS failure		Human error	1			3	N/A	U	1	3	2	6
			Mechanical failure	0			3	N/A	U	0	3	2	6
Scenario 13: Indoor HEUN Solution Water Overfill Spill													
UDB5.14	Nitrogen supply fails high (for Rosemount system)		Human error	1			3	N/A	U	1	3	2	6

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure	0			3	N/A	U D	0 3	3 2	2 2	6 4
UDB5.16 UDB5.18 UDB5.20 UDB5.22 UDB5.24 UDB5.26 UDB5.28 UDB5.30 UDB5.32	Valve BA-4B25 fails open Valve BA-4B26 fails open Valve BA-4B27 fails open Valve BA-4B28 fails open Valve BA-4B29 fails open Valve BA-4B30 fails open Valve BA-4B31 fails open Valve BA-4B32 fails open Valve BA-4B33 fails open		Human error	1			3	N/A	U D	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U D	0 3	3 2	2 2	6 4
UMM8.12	Valve BA-4A25/26/27/28/29/30/31 fails open		Human error	1			3	N/A	U D	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U D	0 3	3 2	2 2	6 4

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative / Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
U Metal Oxidation and Dissolution													
1UMD1.147 2UMD2.147	Valve BA-3A74 or BA-3B47 fails open		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 2
1UMD1.148 2UMD2.148	Valve BA-3A74 or BA-3B47 fails closed		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 2

Item	What if...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
1UMD1:156 2UMD2:156	Valve HV-3A22E or HV-3B22E fails open		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
3DT3:1 3DT3:2 3DT3:3	Valve BA-3C34 fails open or Valve BA-3C35 fails open or Valve BA-3C36 fails open		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
3DT3:11	Nitrogen supply fails high (for Rosemount system)		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
3DT3.33	Operator not present or becomes incapacitated		Emergency evacuation	1			3	N/A	U C	1 4	3 1	2 2	6 2
7DT4.1 7DT4.2 7DT4.3 7DT4.4 7DT4.5 7DT4.6	Valve BA-3D37 fails open or Valve BA-3D38 fails open or Valve BA-3D39 fails open or Valve BA-3D40 fails open or Valve BA-3D41 fails open or Valve BA-3D42 fails open		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4
7DT4.17	Nitrogen supply fails high (for Rosemount system)		Human error	1			3	N/A	U C	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U C	0 3	3 2	2 2	6 4

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
7D4.45	Operator not present of becomes incapacitated		Emergency evacuation	1			3	N/A	U D	1 4	3 1	2 2	6 2
UALAC37.3	Valve BA-1140/41/42 fails open		Human error	1			3	N/A	U D	1 4	3 1	2 2	6 2
			Mechanical failure	0			3	N/A	U D	0 3	3 2	2 2	6 4
UALAC37.38	Operator not present of becomes incapacitated		Emergency evacuation	1			3	N/A	U D	1 4	3 1	2 2	6 2

Table 4-14
Fire Safety Risk Assessment

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
High Consequence													
Scenario number 8; Red Oil Explosion													
1PX10.55	Controller LC-2A11B fails high		Human error 1PX10.2 Valve PCV-2A05 fails high	1			2	6	U C	1 9	3 1	3 3	9 3

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure IPX10.2 Valve PCV 2A05 fails high	0			2	6	C	0	3	3	9

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS Effectiveness of Protection Index	IROFS Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure 1PX10.57 1PX10.63	Flow switch FSL-2A12 fails up; Fails to sense loss of column interface and does not secure power to PUMPMT-2A12 or PUMPMT-2A12 fails to shutdown when flow switch FSL-2A12 senses a loss of column interface. PUMPMT-2A12 fails on		Human error Mechanical failure				2 dur = 3	2	U	2 7	3 1	3	9 3
IROFS failure	PSH-2017 fails to sense steam pressure at 15 psig and does not shut down heaters 2018/2019		Human error Mechanical failure				2 dur = 2	2	U	2 6	3 1	3 3	9 3

Item	What if...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index I	Likelihood Category	Consequence Category	Risk Index
IROFS failure	TE-2018A Fails to sense 121C (250F) temperature and does not shutdown Heaters 2018/2019		Human error Mechanical failure				2 dur. = 2	2	U C	2 6	3 1	3 3	9 3
IROFS failure	Evaporator solution temperature located on the hot leg side of Evaporator 2016 does not sense 110 C (230F) and does not shutdown 2018/2019		Human error Mechanical failure				2 dur. = 2	2	U C	2 6	3 1	3 3	9 3
IROFS failure	Evaporator solution temperature located on the hot leg side of Evaporator 2016 does not sense 110 C (230F) and does not shutdown 2018/2019		Human error Mechanical failure				2 dur. = 2	2	U C	2 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	PSH-2017 fails to sense steam pressure at 15 psig and does not shut down heaters 2018/2019		Human error Mechanical failure				2 dur 2	2	U O	2 6	3 1	3 3	9 3
IROFS failure	Fails to sense 121C (250F) temperature and does not shutdown Heaters 2018/2019		Human error Mechanical failure				2 dur 2	2	U O	2 6	3 1	3 3	9 3
2PSX13-35	Controller LC-2B11B fails high		Human error 2PSX13-90 Valve PCV-2B15 fails high	1			5	6	U O	1 12	3 1	3 3	9 3

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure 2PSX13.90 Valve PCV-2B15 fails high	0			5	6	U G	0 IT	3 I	3	9

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure 2PSX13:37 2PSX13:41	Flow switch FSL-2B12 fails up; Fails to sense loss of column interface and does not secure power to PUMPMT-2B12 or PUMPMT-2B12 fails to shutdown when flow switch FSL-2B12 senses a loss of column interface. PUMPMT-2B12 fails on		Human error Mechanical failure				2 dur 3	2	U C	2 7	3 1	3 3	9 3
IROFS failure	PSH-2P17 fails to sense steam pressure at 15 psig and does not shut down heaters 2P18/2P19		Human error Mechanical failure				2 dur 2	2	U C	2 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	TE-2P18A fails to sense 121C (250F) temperature and does not shutdown Heaters 2P18/2P19		Human error Mechanical failure				2 dur = 2	2	U G	2 6	3 1	3 3	9 3
IROFS failure	Evaporator solution temperature located on the hot leg side of Evaporator 2P16 does not sense 110 C (230F) and does not shutdown 2P18/2P19		Human error Mechanical failure				2 dur = 2	2	U G	2 6	3 1	3 3	9 3
IROFS failure	Evaporator solution temperature located on the hot leg side of Evaporator 2P16 does not sense 110 C (230F) and does not shutdown 2P18/2P19	1	Human error Mechanical failure				2 dur = 2	2	U G	2 6	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index I	Likelihood Category	Consequence Category	Risk Index
IROFS failure	PSH-2P17 fails to sense steam pressure at 15 psig and does not shut down heaters 2P18/2P19		Human error Mechanical failure				2 dur = 2	2	U C	2 6	3 1	3 3	9 3
IROFS failure	Fails to sense 121C (250F) temperature and does not shutdown Heaters 2P18/2P19		Human error Mechanical failure				2 dur = 2	2	U C	2 6	3 1	3 3	9 3
IROFS failure 2PSX13.7I	Interface is lost in Phosphate Scrub Column 2B16		Human error Mechanical failure				3 dur = 0	2	U C	3 5	2 1	3 3	8 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	PSH-2P17 fails to sense steam pressure at 15 psig and does not shut down heaters 2P18/2P19		Human error Mechanical failure				2 dur=2	3	U C	2 7	3 1	3 3	9 3
IROFS failure	TE-2P18A fails to sense 121C (250F) temperature and does not shutdown Heaters 2P18/2P19		Human error Mechanical failure				2 dur=2	3	U C	2 7	3 1	3 3	9 3
IROFS failure	Evaporator solution temperature located on the hot leg side of Evaporator 2P16 does not sense 110 C (230F) and does not shutdown 2P18/2P19		Human error Mechanical failure				2 dur=2	3	U C	2 7	3 1	3 3	9 3
IROFS failure	Interface is lost in Phosphate Scrub Column 2B16		Human error Mechanical failure				3 dur=0	2	U C	3 5	2 1	3 3	6 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index 1	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Flow switch FSL-2B12 fails up; Fails to sense loss of column interface and does not secure power to PUMPMT-2B12 or PUMPMT-2B12 fails to shutdown when flow switch FSL-2B12 senses a loss of column interface		Human error Mechanical failure				2 dur 3	3	[illegible]	2 8	3 1	3 3	9 3
IPE12-185	Temperature rises in the evaporator. (Assuming solvent is in the evaporator Reflux Column 2013) due to self-heating		Human error (Solvent in Reflux Column 2013)	1			3	3	[illegible]	1 5	3 1	3 3	9 9

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure (Solvent in Reflux Column 2013)	1			3	3	U G	1 3	3 1	3 3	9 3
IROFS failure (PE12.90 (PE12.92	The reflux column vent through the 1 inch WOG that vents through Demister 2020 and Condenser 2021 plugs during a red oil pressure excursion (no self-heating)		Human error Mechanical failure Foreign Material				3 dur = 4	3	U C	3 10	2 1	3 3	6 3

Item	What if...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure 1PE12.88	The reflux column vent through the WOG liquid filled 3 psig dog-leg to Knockout Column 2108 and siphon break plugs during a red oil pressure excursion (no self-heating)		Human error Mechanical failure Foreign Material				3 dur = 4	3	U O	3 10	2 1	3 3	6 3
IROFS failure	The reflux column vent through the 1 inch WOG that vents through Demister 2020 and Condenser 2021 plugs during self-heating		Human error Mechanical failure Foreign Material				3 dur = 0	3	U O	3 6	2 1	3 3	6 3
IROFS failure	The reflux column vent through the WOG liquid filled 3 psig dog-leg to Knockout Column 2108 and siphon break plugs during self-heating		Human error Mechanical failure Foreign Material				3 dur = 0	3	U O	3 6	2 1	3 3	6 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index (I)	Likelihood Category	Consequence Category	Risk Index
IPE12.186	Solvent is dumped to concentrate hold COLUMNs-2014/2024 at <110°C (230°F) when the reflux column solution density measurement reached the designed density and self-heating occurs (there is no external heat source to the concentrate hold columns)		Human error (Solvent in Reflux Column-2013)	1			3	3	U G	1 5	3 1	3 3	9 3
			Mechanical failure (Solvent in Reflux Column-2013)	1			3	3	U G	1 5	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Concentrate Hold Columns 2014/2024 WOG that vents through the ¼ inch tubing to Knockout Column 2108 and siphon break plugs during self-heating		Human error Mechanical failure Foreign Material				3 durin 0	3	U C	3 6	2 1	3 3	6 3
IROFS failure	Concentrate Hold Columns 2014/2024 vent through the (separate from IROFS BSX-23) independent WOG vent to Knockout Column 2108 and siphon break plugs during self-heating		Human error Mechanical failure Foreign Material				3 durin 0	3	U C	3 6	2 1	3 3	6 3
1PE12187	Solvent is pumped to downstream columns in solvent extraction at <110°C (230°F) from the concentrate hold columns 2014/2024 and self-heating occurs (there is no external heat source to the downstream columns)		Human error Solvent in concentrate hold COLUMNs 2014/2024	1			2	3	U C	1 4	3 1	3 3	9 3

Item	What if?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index 1	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure Solvent in concentrate hold COLUMNs 2014/2024	1			2	3	U C	1 4	3 1	3 3	9 3
IROFS failure	Operator does not verify that solvent is in Concentrate Hold Columns 2014/2024 prior to transfer to downstream columns		Human error Mechanical failure Foreign Material				2 dur = 0	3	U C	2 5	3 1	3 3	9 3
IROFS failure	Columns downstream of Concentrate Hold Columns 2014/2024 are not vented through a Knockout Column and siphon break		Human error Mechanical failure Foreign Material				3 dur = 0	2	U C	3 5	2 1	3 3	6 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
2PE15:155	Temperature rises in the evaporator. (Assuming solvent is in the evaporator Reflux Column 2P13) due to self-heating		Human error (Solvent in Reflux Column 2P13)	1			3	3	U C	1 5	3 1	3 3	9 3

Item	What If.?2	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure (Solvent in Reflux Column 2P13)	1			3	3	U	1	3	3	9
IROFS failure 2PE15.84 2PE15.86	The reflux column vent through the 1 inch WOG that vents through Demister 2P20 and Condenser 2P21 plugs during a red oil pressure excursion (no self-heating)		Human error Mechanical failure Foreign Material				3 dur 4	3	U	3 10	2 1	3 3	6

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
IROFS failure 2PE15.82	The reflux column vent through the WOG liquid filled 3 psig dog-leg to Knockout Column 2I08 and siphon break plugs during a fed oil pressure excursion (no self-heating)		Human error Mechanical failure Foreign Material				3 dur = 4	3	U C	3 10	2 1	3 3	6 3
IROFS failure	The reflux column vent through the 1 inch WOG that vents through Demister 2P20 and Condenser 2P21 plugs during self-heating		Human error Mechanical failure Foreign Material				3 dur = 0	3	U C	3 6	2 1	3 3	6 3
IROFS failure	The reflux column vent through the WOG liquid filled 3 psig dog-leg to Knockout Column 2I08 and siphon break plugs during self-heating		Human error Mechanical failure Foreign Material				3 dur = 0	3	U C	3 6	2 1	3 3	6 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
2PE15.156	Solvent is dumped to concentrate hold COLUMN-2P14 at <110°C (230°F) when the reflux column solution density measurement reached the designed density and self-heating occurs (there is no external heat source to the concentrate hold columns)		Human error (Solvent in Reflux Column-2P13)	1			3	3	U	1	3	3	9
			Mechanical failure (Solvent in Reflux Column-2O13)	1			3	3	U	1	3	3	9

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS Effectiveness of Protection Index	IROFS Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Concentrate Hold Column 2P14 WOG that vents through the ¾ inch tubing to Knockout Column 2108 and siphon break plugs during self-heating		Human error Mechanical failure Foreign Material				3 dur 0	3	U C	3 6	2 1	3 3	6 3
IROFS failure	Concentrate Hold Column 2P14 vent through the (separate from IROFS BSX-29) independent WOG vent to Knockout Column 2108 and siphon break plugs during self-heating		Human error Mechanical failure Foreign Material				3 dur 0	3	U C	3 6	2 1	3 3	6 3
2PE15:157	Solvent is pumped to downstream columns in solvent extraction at <110°C (230°F) from the concentrate hold column 2P14 and self-heating occurs (there is no external heat source to the downstream columns)		Human error Solvent in concentrate hold COLUMN-2P14	1			2	3	U C	4	3 1	3 3	9 3

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
			Mechanical failure Solvent in concentrate hold COLUMN-2P14	1			2	3	U G	1 4	3 1	3 3	9 3
IROFS failure	Operator does not verify that solvent is in Concentrate Hold Column 2P14 prior to transfer to downstream columns		Human error Mechanical failure Foreign Material				2 dur = 0	3	U G	2 5	3 1	3 3	9 3
IROFS failure	Columns downstream of Concentrate Hold Column 2P14 are not vented through a Knockout Column and siphon break		Human error Mechanical failure Foreign Material				3 dur = 0	2	U G	3 5	2 1	3 3	6 3
Fire scenarios consequences are Bounded by the following assumpation designated as IROFS (21T-03-1184)													
BSX-35	Solvent Extraction Process Area (excluding SX Product Columns) is enclosed by a Two-Hour Rated Firewall on the first floor and the North walls on the 2nd and 3rd floor												
BSX-36	Mechanical Room containing the Solvent Extraction Chemical Makeup Process is isolated from the BPF Processes by a One-Hour Rated Firewall on the North wall												
BSX-37	Dike shall be designed and installed to contain a solution spill of at least 110 gallons of Solvent from the First Pass Solvent Extraction Process Area												
BSX-38	Dike shall be designed and installed to contain a solution spill of at least 110 gallons of Solvent from the Second Pass Solvent Extraction Process Area												
BSX-39	Sump shall be designed and installed to contain a solution spill of at least 100 gallons of Solvent from the Solvent Extraction Makeup Area Solvent TANK-2L031												

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
Scenario 5, Scenario 2, Hydrogen, Aluminum Dissolvers A, B, C, and D are duplicate processes. Risk indexing is performed for the A process. B, C and D IROFS are identical to A IROFS. The Caustic and Sodium nitrate feed valves for processes A, B, C and D are as follows: Caustic Feed (A) 1K06; (B) 1K05; (C) 1K04; (D) 1K03 Sodium Nitrate Feed (A) 1K10; (B) 1K09; (C) 1K08; (D) 1K07													
IROFS failure CMST38.16 CMST38.17 CMST38.18 CMST38.19 PUMPMT-1K06/1K10 fail on CMST38.31 CMST38.32 CMST38.33 CMST38.34 Valve 1K06/1K10 fail open Risk only shown for A! B, C and D are duplicate IROFS includes B, C and D Cause includes B, C and D	BUA-23/24/25/26 Interlock #6/7/8/9 fails Valve HV-1A01B and HV-1A11A do not open initiating a nitrogen purge (or nitrogen flow is secured or degraded) to Dissolvers 1A01 and 1A11 HV-1A01A does not open initiating a nitrogen purge (or nitrogen flow is secured or degraded) to Enclosure 1A06 PUMPMT-1K06/1K10 do not stop and Valves 1K06 and 1K10 do not shut securing caustic and sodium nitrate flow to Dissolvers 1A01 and 1A11 Heater-1A08 does not shutdown on Hydrogen detected in Enclosure 1A06 as indicated on AIT-1A06		Human error Mechanical failure 1UALD29.84 2UALD30.84 3UALD31.84 4UALD32.84 Exhaust HEPA filter HEPA 6G02/3/4/5 plugs 1UALD29.70 2UALD30.70 3UALD31.70 4UALD32.70 POG line plugs 1UALD29.23 2UALD30.23 3UALD31.23 4UALD32.23 Valve PCV-1A01 fails low 1UALD29.25 2UALD30.25 3UALD31.25 4UALD32.25 Valve BA-1A35 fails closed				2 dur=0	2	U G	2 4	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index 1	Likelihood Category	Consequence Category	Risk Index
			1UALD29.26 2UALD30.26 3UALD31.26 4UALD32.26 Flowmeter FIC-1A01 fails high (indicates high actual condition is low) 1UALD29.30 2UALD30.30 3UALD31.30 4UALD32.30 Nitrogen line breaks 1UALD29.78 2UALD30.78 3UALD31.78 4UALD32.78 Valve HV-1A01B/HV-1A11A fails closed 1UALD29.80 2UALD30.80 3UALD31.80 4UALD32.80 Valve HV-1A01A fails closed										

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
			PV443 Balance of plant ventilation butterfly/damper valves misaligned										
IROFS failure CMST38.31 CMST38.32 CMST38.33 CMST38.34 Valve 1K06/1K10 fail open	BUA 28/29/30/31 Interlock # 135/136/137/138 fails. HV-1K06 does not shut securing caustic flow to Dissolvers 1A01 and 1A11 Upon detection of low negative pressure at Pressure Switch PSL-1A05		Human error Mechanical failure				2 dur=0	2	UC	2	3	[illegible]	[illegible]

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
IROFS failure 1UALD29.66 2UALD30.66 3UALD31.66 4UALD32.66 Risk only shown for A B, C and D are duplicate IROFS includes B, C and D Cause includes B, C and D	BUA32/33/34/35 Passive Engineering Control, WOG/POG line for Dissolvers 1A01/1AT1 through Demister 1A05 and Condenser 1A04 to ventilation hydrogen dilution system plugs! Hydrogen dilution system is not capable of maintaining vacuum in the WOG/POG line through EJECTR-6G13 using air from Pressure Control Valve PCV-6G13		Foreign Material 1UALD29.48 2UALD30.48 3UALD31.48 4UALD32.48 (WOG-POG) Demister 1A05/1B05/ 1C05/1D05 fails plugged 1UALD29.49 2UALD30.49 3UALD31.49 4UALD32.49 Valve BA-1A4T fails open				3 dur = 3	2	U C	3 8	2 1	3 3	6 3
IROFS Failure CMST38.31 CMST38.32 CMST38.33 CMST38.34 Valve 1K06/1K10 fail open	BUA 28/29/30/31 Interlock # 135/136/137/138 fails HV-1K06 does not shut securing caustic flow to Dissolvers 1A01 and 1AT1 Upon detection of low negative pressure at Pressure Switch PSL-1A05		Human error Mechanical failure				2 dur = 0	3	U C	2 5	3 1	3 3	9 3

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
IROFS failure			Mechanical failure				3 [illegible]	2	U G	3 [illegible]	2 [illegible]	3 [illegible]	6 [illegible]
1UALD29.45 2UALD30.45 3UALD31.45 4UALD32.45	BUA-8 Condenser CONDEN-1A04 leaks												
1UALD29.49 2UALD30.49 3UALD31.49 4UALD32.49	BUA-36/37/38/39 Valve BA-1A41 is not shut during dissolution (fails open)												
Risk only shown for A B, C and D are duplicate	(water into fissile solution)												
IROFS includes B, C and D													
Cause includes B, C and D													

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index I	Likelihood Category	Consequence Category	Risk Index
IROFS failure			Mechanical failure				2 during O	2	UG	2	3	3	9
1UALD29.45	BUA-8		1UALD29.23										
2UALD30.45	Condenser CONDEN		2UALD30.23										
3UALD31.45	1A04 leaks		3UALD31.23										
4UALD32.45			4UALD32.23										
			Valve PCV1										
1UALD29.49	BUA-36/37/38/39		1A01 fails low										

Item	What If...?	Controls (Defense In Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
2UALD30.49 3UALD31.49 4UALD32.49 Risk only shown for A B, C and D are duplicate IROFS includes B, C and D Cause includes B, C and D	Valve BA-1A41 is not shut during dissolution (fails open) (water into fissile solution)		1UALD29.25 2UALD30.25 3UALD31.25 4UALD32.25 Valve BA-1A35 fails closed 1UALD29.26 2UALD30.26 3UALD31.26 4UALD32.26 Flowmeter FIC-1A01 fails high (indicates high actual condition is low) 1UALD29.30 2UALD30.30 3UALD31.30 4UALD32.30 Nitrogen line breaks 1UALD29.78 2UALD30.78 3UALD31.78 4UALD32.78 Valve HV-1A01B/HV-1A11A fails closed 1UALD29.80 2UALD30.80 3UALD31.80										

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
			4UALD32.80 Valve HV-1A01A fails closed										
IROFS failure CMST38.16 CMST38.17 CMST38.18 CMST38.19 PUMPMT-1K06/1K10 fail on CMST38.31 CMST38.32 CMST38.33 CMST38.34 Valve	BUA-15/17/19/21 UAL Interlock #2/3/4/5 fails; Valve HV-1A01B and HV-1A11A do not open initiating a nitrogen purge to (or nitrogen flow is secured or degraded) Dissolvers 1A01 and 1A11 HV-1A01A does not open initiating a nitrogen purge to (or nitrogen flow is secured or degraded) Enclosure 1A06		Mechanical failure 1UALD29.23 2UALD30.23 3UALD31.23 4UALD32.23 Valve PGV-1A01 fails low 1UALD29.25 2UALD30.25 3UALD31.25 4UALD32.25 Valve BA-1A35 fails closed				2 durc=0	3	U	2	3	3	9

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index #	Likelihood Category	Consequence Category	Risk Index
1K06/1K10 fail open	PUMPMT-1K06/1K10 do not stop and Valves 1K06 and 1K10 do not shut securing caustic and sodium nitrate flow to Dissolvers 1A01 and 1A11 Heater-1A08 does not shutdown on Dissolver 1A01 High Level as indicated on LSH-1A01 BUA-16/18/20/22 Interlock # 104/105/106/107 fails Valve HV-1A01B and HV-1A11A do not open initiating a nitrogen purge to (or nitrogen flow is secured or degraded) Dissolvers 1A01 and 1A11 HV-1A01A does not open initiating a nitrogen purge to (or nitrogen flow is secured or degraded) Enclosure 1A06 PUMPMT-1K06/1K10 do not stop and Valves 1K06 and 1K10 do not shut securing caustic and sodium		1UALD29.26 2UALD30.26 3UALD31.26 4UALD32.26 Flowmeter FIC-1A01 fails high (indicates high actual condition is low) 1UALD29.30 2UALD30.30 3UALD31.30 4UALD32.30 Nitrogen line breaks 1UALD29.78 2UALD30.78 3UALD31.78 4UALD32.78 Valve HV-1A01B/HV-1A11A fails closed 1UALD29.80 2UALD30.80 3UALD31.80 4UALD32.80 Valve HV-1A01A fails closed									

Item	What If/?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index
	nitrate flow to Dissolvers 1A01 and 1A11 Heater-1A08 does not shutdown on Dissolver 1A11 High Level as indicated on LSH? 1A11												
Intermediate Consequence													
1UALD29.88 2UALD30.88 3UALD31.88 4UALD32.88 Risk only shown for A B, C and D are duplicate IROFS includes B, C and D Cause includes B, C and D	Demister 1A05 Drain line plugs		Foreign material	2			2	N/A	U	2	E	N	6

Item	What If?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative / Preventive IROFS and IROFS failure	Mitigative / Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index II	Likelihood Category	Consequence Category	Risk Index

Item	What If...?	Controls (Defense in Depth)	Cause	Initiating Event Failure Frequency Index Number	Mitigative/ Preventive IROFS and IROFS failure	Mitigative/ Preventive IROFS and IROFS failure	IROFS1 Effectiveness of Protection Index	IROFS2 Effectiveness of Protection Index		Likelihood Index	Likelihood Category	Consequence Category	Risk Index
CMST38.20 CMST38.36 CMST38.47 Risk only shown for A B, C and D are duplicate IROFS includes B, G and D Cause includes B, G and D	PUMPMT 1K07/1K08/1K09/1K10 falls off Valves HV 1K07/1K08/1K09/1K10 falls closed Valves BA-54/55/57/57 fail closed		Human error Mechanical failure	1			2	N/A	U G	T 3	3 2	2 2	6 4

4.4 MANAGEMENT MEASURES FOR IROFS

Management Measures are defined for credited IROFS to ensure they are available and reliable to perform their required function when needed (10 CFR 70.62.d). The defined set of Management Measures for each IROFS will consist of selected elements of the following management measure programs:

- Configuration Management
- Maintenance
- Training and Qualification
- Procedures
- Audits and Assessments
- Incidents and Investigations
- Records Management
- Other Quality Assurance Elements

The type of IROFS control (passive, active, enhanced administrative or administrative), along with the risk reduction level credited in the ISA, will determine the level of management measures applied to each IROFS.

The four types of IROFS controls, along with the management measures that apply to them are shown in Table 4-15.

Not all of the listed management measures would be applied to each IROFS. The management measures applied to a particular IROFS will be graded commensurate with the level of risk reduction credited for that IROFS in the ISA. High or Intermediate consequence events depend on IROFS to reduce the overall risk to an acceptable level. High consequence events must be justified as highly unlikely, and intermediate consequence events justified as unlikely, after implementation of credited IROFS.

Table 4-15 defines how management measures are applied in a graded approach based on Risk Reduction levels credited in the ISA (Level A or B). IROFS credited with a high level of risk reduction (Level A) will require a high level of management measures to ensure a high level of reliability. IROFS credited with an intermediate level (Level B) of risk reduction, or intermediate failure likelihood, will require an intermediate level of management measures. Administrative IROFS that encompass operation of an active component shall require management measure application as specified for enhanced administrative controls to its respective component.

The applicable management measures identified in Table 4-15 are applied based on the type of control to ensure that the credited IROFS failure index meets the risk index specified or the design basis thresholds for events associated with natural phenomena. Information to justify a deviation from a management measure contained in Table 4-15 associated with a specific IROFS will be documented.

Table 4-15 specifies that records management and QA requirements will be adhered to as management measures to ensure the IROFS reliability and availability, and that when demanded the IROFS prevents or mitigates the accident sequence to meet the performance requirements. These management measures will be applied to the design, construction, operations, maintenance and change control of IROFS functional boundaries and identified subsystems. All IROFS boundary equipment and essential utilities will be purchased, inventoried and installed in accordance with engineering design specifications to ensure they are reliable and available to perform their intended function and meet the performance criteria. Management measure Category A IROFS as specified in Table 4-15 will require functional testing. Documentation of the above steps will be maintained in the ISA files for individual IROFS.

Maintenance, calibration, testing, and/or inspection of IROFS and other safety related equipment to ensure continued reliability and functional acceptability will be performed in accordance with written procedures. Frequencies will be established based on manufacturer and industry guidance, with approval by the safety review committee. If an IROFS or other safety related equipment has undergone maintenance, or has been inactive for an extended period, it shall be functionally tested, calibrated, or inspected (as applicable) prior to restart.

Set points for IROFS interlocks and alarms shall be selected using conservative engineering analyses which account for safety limits, instrument and system accuracies, response times, instrument drift, manufacturer's data and operating experience. The analysis for each safety setpoint shall be a formal calculation and shall be documented for each applicable IROFS. Calibration and functional test frequencies should also consider data used in the setpoint determinations.

Detailed descriptions of each of the eight management measure program elements can be found in Section 2.12 of SNM-124, "Management Measures for Items Relied on For Safety".

Table 4-15
Management Measures for IROFS

CONTROL TYPE/Measures	RISK REDUCTION LEVEL	
	A IROFS credited with a high level of Risk Reduction for High or Intermediate Consequence events	B IROFS credited with a moderate level of Risk Reduction for Intermediate Consequence events
ACTIVE ENGINEERED CONTROLS		
Periodic Functional Test	x	
Maintenance	x	x
Verification After Maintenance	x	
Calibration	x	x
Controlled Listing Identification	x	
Drawing Identification	x	
Procedural Identification	x	x
Pre-operational Audits or Tests	x	x
Periodic Audits	x	x
Training and Qualifications	x	
Records Management, Investigations, and other quality assurance elements	x	
PASSIVE ENGINEERED CONTROLS		
Maintenance	x	x
Verification After Maintenance	x	
Controlled Listing Identification	x	
Procedural Identification	x	x
Pre-operational Audits or Tests	x	x
Independent Installation Verification	x	
Periodic Audits or Inspections	x	x
Vendor Specifications	x	
Training and Qualifications	x	
Records Management, Investigations, and other quality assurance elements	x	
ADMINISTRATIVE CONTROLS		
Procedural or Posting Identification	x	x
Pre-operational Audits	x	x
Periodic Audits	x	x
Training and Qualification	x	
Testing of Training Effectiveness	x	
Records Management, Investigations, and other quality assurance elements	x	
ENHANCED ADMINISTRATIVE CONTROLS		
Periodic Functional Test	x	
Calibration	x	x
Maintenance	x	x
Verification After Maintenance	x	
Controlled Listing Identification	x	x
Drawing Identification	x	x
Procedural or Posting Identification	x	x
Pre-operational Audits	x	x
Periodic Audits	x	x
Training and Qualifications	x	
Testing of Training Effectiveness	x	
Records Management, Investigations, and other quality assurance elements	x	

*Note: The Management Measures identified for each risk reduction level are the minimum if applicable. For example, it is not possible to calibrate certain types of active engineered controls. The controls may be increased based on the specific IROFS involved, the credited risk reduction, industry standards, vendor specifications, or engineering recommendations.

5.0 ISA TEAM AND ISA METHOD

5.1 ISA TEAM

The ISA Team for BPF operations normally consists of 5-8 members (may include more if necessary). The minimum team is defined by the Vice President, Safety and Regulatory, to meet the requirements of 10 CFR 70.62. The team is required to have an appointed Team Leader and normally consists of members from the following disciplines: 1) criticality safety, 2) radiological safety, 3) fire safety, 4) chemical process safety, 5) project engineering, 6) maintenance and 7) environmental safety. Members have at least 1 year of experience in the safety discipline represented. A single member may be knowledgeable in more than one area, and therefore may be relied upon to provide analysis expertise in more than one area. The Team consults with additional safety, operations, engineering and maintenance personnel on an as-needed basis.

The ISA Team Leader is expected to be cognizant of the requirements for Integrated Safety Analyses as prescribed in 10 CFR Part 70 as well as the applicable NRC guidance in NUREG-1520 "Standard Review Plan". Guidance is also provided in NUREG-1513, NUREG/CR6410, and the AIChE publication, "Guidelines for Hazard Evaluation Procedures."

The ISA Team for the BPF consisted of the following personnel:

- Thomas Barry, Fire Protection, HSB Professional Loss Control
- Joseph Chew, Industrial Safety Specialist, NFS
- Michael Corum, Nuclear Criticality Safety, NuclearSafety Associates (NSA)
- Allen Cure, Health Physicist, NFS
- Brian Faidley, Maintenance / Operations, NFS
- Scott Gizzie, Nuclear Criticality Safety, NFS
- Brian Gleckler, Health Physicist, NFS
- Joyce Griffith, Environmental Scientist, NFS
- Tim Heagle, Project Engineer, NFS
- David Hopson, ISA Team Leader, NFS (ISA Team Leader training, Process Safety Institute, Knoxville, TN)
- Bryan Long, Project Engineer, NFS
- Carol Mason, Chemical Engineer, SAIC
- Robert Maurer, Nuclear Criticality Safety, NSA
- Chris Miller, Nuclear Criticality Safety, NFS
- Jimmy Napier, Environmental Scientist, NFS
- L. Randy Sanders, Team Leader, NFS (ISA Team Leader training by Process Safety Institute, Knoxville, TN)
- Sonya Sanders, Health Physicist, NFS
- Sam Skiles, Nuclear Criticality Safety, NSA

- Brad Smythe, Project Engineer, NFS
- Gail Tapp, Industrial Safety Specialist, NFS

Table 5-1 ISA Team Members

ISA TEAM LEADER	CRITICALITY SAFETY	RADIOLOGICAL SAFETY	FIRE SAFETY	CHEMICAL PROCESS SAFETY	PROJECT ENGINEERING / MAINTENANCE	ENVIRONMENTAL SAFETY
L. R. Sanders D. R. Hopson	M. Corum S. Gizzie R. Maurer C. Miller S. Skiles	A. Cure Sonya Sanders L. R. Sanders	J. Chew T. Barry	G. Tapp C. Mason	B. Faidley T. Heagle B. Long B. Smythe	J. Napier B. Gleckler J. Griffith

5.2 ISA METHOD

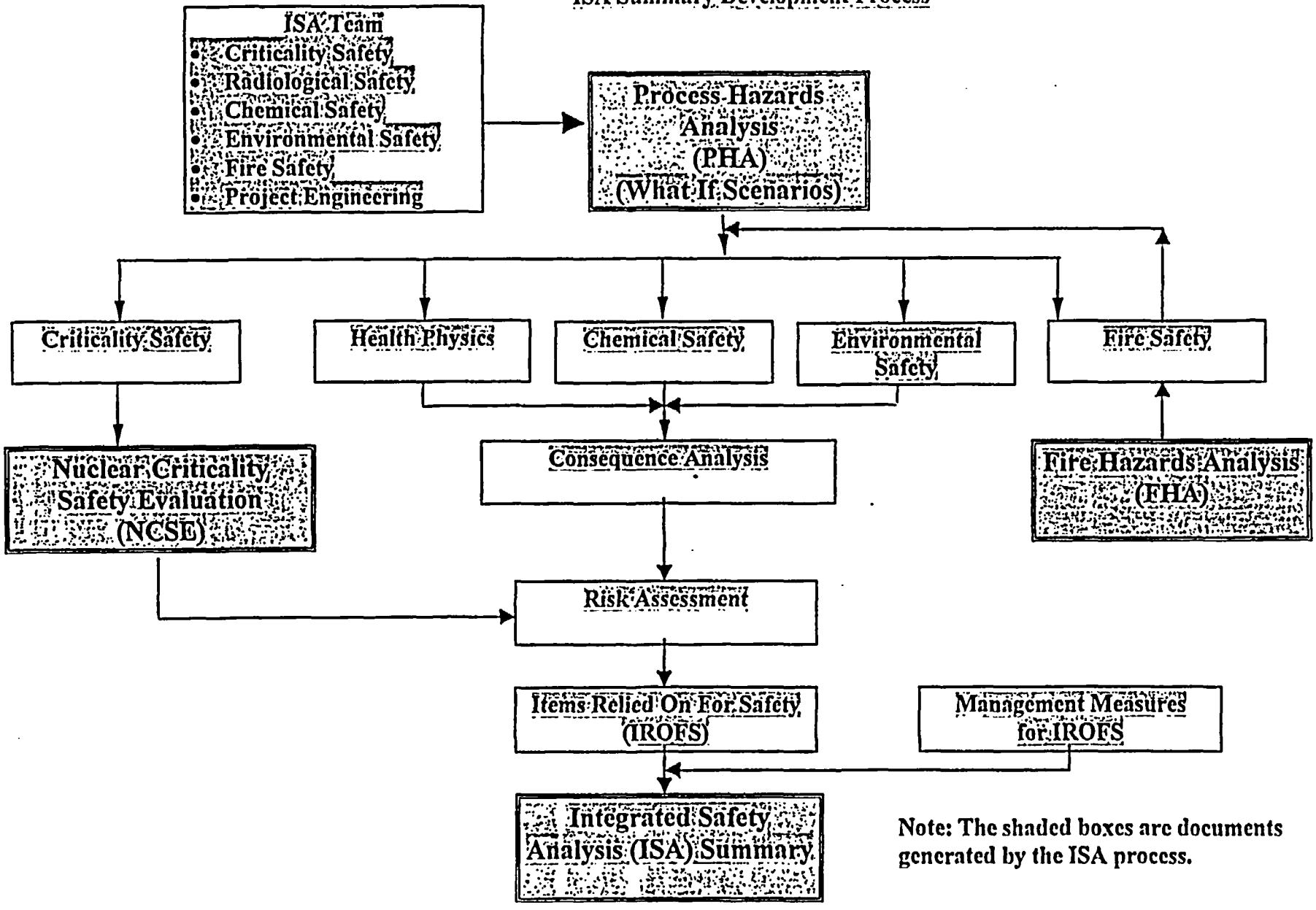
The ISA Summary development process is shown in Figure 5-1, and is conducted in basically five phases: 1. First, individual and specific hazards analyses are performed to identify hazards and accident sequences. From the hazard analyses, specific accident sequences are defined for consequence analysis. 2. Accident consequences are determined for the defined accident sequences based on unmitigated conditions for comparison with the 10 CFR 70.61 exposure criteria. 3. The third step is Risk Assessment, where each high or intermediate consequence event is evaluated to determine if the active, passive, or administrative controls proposed are adequate to make the postulated events highly unlikely or unlikely. 4. Next, IROFS are identified which control all accidents resulting in consequences of concern, to an acceptable risk. The IROFS list is generated and evaluated for adequacy. 5. The final step involves development of management measures for the identified IROFS to ensure they will be available and reliable to perform their required function.

5.2.1 Process Hazards Analysis(es)

Identification of hazards and accident conditions that lead to undesirable consequences is accomplished by conducting a Process Hazards Analysis (PHA). A PHA is conducted on each process system with joint consideration of radiological, criticality, fire, and chemical hazards using appropriate methodologies as prescribed in "Guidelines for Hazards Evaluation Procedures", (Reference 1). A qualified team is utilized in the conduct of the PHA. Specifically included in the PHA team meetings are; 1) a team leader trained in the methodology(ies) being used, 2) a person familiar with the design, and operation of the process, 3) one or more persons familiar with radiological, chemical, fire, and criticality safety.

NON-

Figure 5-1
ISA Summary Development Process



Note: The shaded boxes are documents generated by the ISA process.

During the conduct of the PHA, process safety information is collected and then reviewed for completeness. The team leader then selects the methodology to be used for identifying accident sequences. For the BPF, the "What-If" methodology was selected. This methodology involves a detailed evaluation by the ISA team for each BPF process, including the utility and auxiliary support systems, to determine the potential impact of specific component failures. The ISA team evaluates the consequences of all types of failures for each valve, tank, pipe, or control system identified on the system design drawings. Each credible failure mode for each component is identified as a specific accident sequence, and specific types of consequences are identified for each sequence (radiological release, chemical release, criticality, fire, etc.)

5.2.2 Consequence Analysis

After identification of the accident sequences, the specific sequences are evaluated and grouped to determine the consequences for worker or public exposure. The consequence calculations for specific accident sequences or groups of sequences are reviewed to determine those that exceed or equal the 10 CFR 70.61 levels (Table 5-2). Tables 7-1, 7-2, and 7-3 in Section 7 further define the BPF consequence exposure standards. The results of the consequence analysis for the BPF are reported in Section 4.2.

Nuclear Criticality Safety Evaluation(s)

Nuclear Criticality Safety Evaluations (NCSEs) are specialized studies that assure the risk of having a criticality accident is 'Highly Unlikely' and that the double contingency principle is satisfied. NCSEs are required for all nuclear facilities and contained fissile material units and/or arrays. These evaluations provide the technical basis for specified limits and controls to assure criticality safety. Highly skilled and extensively trained personnel in the area of criticality safety perform NCSEs. In addition, a multi-disciplined team reviews all accident sequences, barriers, and bounding assumptions used in the evaluations.

The criticality hazards and controls from the NCSEs are summarized in Section 3 for each BPF process. The risk assessment and final IROFS defined in the NCSEs are provided in Sections 4.3 and 6.1 respectively. Criticality Safety consequences are not reported in Section 4.2 because the consequence of all credible criticality scenarios is a high consequence event.

Fire Hazards Analysis

A Fire Hazards Analysis (FHA) was conducted for the BPF (Reference 10). The charter of the FHA was to evaluate the facility design with respect to fire safety codes, and to ensure that the facility is built such that there is acceptable risk for postulated fire accident scenarios. The FHA for the BPF was conducted by an

outside consultant that specializes in fire safety. The fire hazards and controls from the FHA are summarized in Section 3 for each process.

The consequences of the postulated fire accident scenarios are determined based on area of facility damage or fire intensity. This information is passed along to the other safety disciplines to determine actual chemical or radiological exposure levels.

Table 5-2: Consequence Severity Categories Based on 10 CFR 70.61

	Workers	Offsite Public	Environment
Consequence Category 3: High	TEDE ≥ 100 rem ≥ ERPG3	TEDE ≥ 25 rem ≥ 30 mg soluble Uranium Intake ≥ ERPG2	
Consequence Category 2: Intermediate	25 rem ≤ TEDE < 100 rem ≥ ERPG2 But < ERPG3	5 rem ≤ TEDE < 25 rem ≥ ERPG1 But < ERPG2	Radioactive Release averaged over a 24 Hour Period of > 5000 x Table 2 Appendix B 10 CFR 20
Consequence Category 1: Low	Accidents of lesser radiological and chemical exposures to workers than those above in this column	Accidents of lesser radiological and chemical exposures off-site than those above in this column	Radioactive releases producing effects less than those specified above in this column.

Note: AEGLs, PELCs, TEELs, or IDLH values are utilized when ERPG values do not exist.

5.2.2.1 Integration

To meet NRC requirements the ISA will only be concerned with major events—"consequences of concern"—and the IROFS necessarily applied to them. The ISA is intended to give assurance that the potential failures, hazards, accident sequences, scenarios, and IROFS have been investigated together so as to adequately consider common mode and common cause situations, impacts of IROFS that may be simultaneously beneficial and harmful with respect to different hazards, and interactions that may not have been considered in previously completed analyses. The multi-discipline ISA team considers the potential interaction and integration issues for each process and utility system review.

Some items that warrant special consideration during the ISA team integration review process are:

- External events. This is due to the broad effects they will usually have on the entire plant site, and because they may not have been fully considered in the individual analyses, which were directed principally toward internal events.
- Common mode failures and common cause situations.

- Closely allied to common cause situations are utility system losses, e.g., loss of electrical power or city water, which can have simultaneous effects on multiple systems.
- Divergent Impacts of IROFS. Assurance must be provided that the negative impacts of an IROFS, if any, do not outweigh its positive impacts; i.e. to ensure that the application of an IROFS for one situation does not degrade a different risk situation. The standard example is use of water in a fire situation, which can add moderation with respect to criticality control.
- Other safety and mitigating factors that do not achieve the status of IROFS that could impact system performance.
- Identification of scenarios, events, or event sequences with multiple impacts, i.e., impacts on chemical safety, fire safety, criticality safety, and/or radiation safety (e.g., a flood might cause both loss of containment and moderation impacts.
- Potential interactions between processes, systems, areas, and buildings; any interdependence of systems, or potential transfer of energy or materials.
- Major hazards or events, which tend to be common cause situations leading to interactions between processes, systems, buildings, etc.

5.2.3 Event Frequency, IROFS, and Risk Categorization

For each credible accident sequence, the initiating event leading to the accident is identified. If a single initiating event cannot be identified, the conditions that must be met to create the accident are analyzed.

An Initiating Event Failure Frequency Index is assigned to each credible accident scenario based on past experience, engineering judgment, analytical data, industry acceptable values, and/or any other applicable information. Initiating Event Failure Frequency is defined as the probability of occurrence of the initiating event or initiating set of conditions. The index assignments are defined in Table 5-3.

Table 5-3: Initiating Event Failure Frequency

Frequency Index	Failure Frequency	Description	Comments
-5	1 Failure/100,000 years	Not credible	If initiating event, no IROFS needed
-4	1 Failure/10,000 years	Physically possible, but not expected to occur.	
-3	1 Failure/1,000 years	Not expected to occur during plant lifetime.	
-2	1 Failure/100 years (Loss of cooling (redundant cooling water pumps)) (Loss of Power (redundant power supplies))	Not expected, but might occur during plant lifetime.	
-1	1 Failure/10 years	Expected to occur during plant lifetime.	
0	1 Failure/year (Loss of cooling) (Loss of Power)	Expected to occur regularly during plant lifetime.	
1	Several occurrences per year	A frequent event	

The index value assigned to an initiating event may be one value higher or lower than the value. Criteria justifying assignment of the adjusted value should be given in the narrative describing ISA methods. Exceptions require individual justification.

Initiating Event Failure Frequency Indices for all credible High or Intermediate consequence accident scenarios are assigned and documented in the Section 4.3 Risk Tables.

Identification of IROFS

Applicable IROFS are identified and assigned to all High or Intermediate consequence accident scenarios.

Items Relied On For Safety (IROFS) means structures, systems, equipment, components and activities of personnel that are relied on to prevent potential accidents at a facility that could exceed the performance requirements of 10 CFR 70.61 or to mitigate their potential consequences.

Accordingly, an IROFS provides a safety function that serves to reduce the risk associated with a specific accident scenario. The components of an IROFS function may include operator actions, equipment, control logic, and elements such as time or margin of safety (see example below). In addition, utility subsystems required to maintain the reliability and availability of an IROFS are bounded within the IROFS function. Utilities not required to meet the performance criteria, such as in fail-safe controls or equipment, do not require inclusion in the IROFS functional boundary.

Equipment, actions, or controls within the IROFS functional boundary equipment and subsystems must be:

- Designed to prevent or mitigate specific, potentially hazardous events. Each identified potential hazard should have corresponding, specific protection strategies.
- Independent so that there is no dependence on components of other protective layers associated with an identified hazard. There must also be no linkage between the initiating event and the ability of the IROFS to perform as required.
- Dependable so that they can be relied on to operate in the prescribed manner. Both random and specific failure modes should be considered in the assessment if there is a probability of protection layers failing on demand or failing during their mission. If human intervention is included as an IROFS, the response time and corresponding human error probability must be considered.
- Auditable in that they are designed to facilitate regular validation (including testing) and maintenance of the protective functions.

Example: an administrative control may require a spill be cleaned up within 8 hours and only if it exceeds 5 gallons (because it is safe if cleaned up in less time or if the volume is below 5 gallons).

Each IROFS is assigned an IROFS Effectiveness of Protection Index as specified in Table 5-4. The Effectiveness of Protection Index is an index assigned to:

1. Qualitatively envelop the protection afforded by an IROFS to prevent or mitigate an accident sequence with the required management measures applied ensuring the IROFS is reliable and available to perform its function upon demand.
2. Qualitatively envelop the protection afforded by an IROFS to prevent or mitigate an accident sequence with the required management measures applied while establishing the vulnerability of the IROFS to an intermediate consequence or the failure of a second IROFS in a high consequence event.

The Index is assigned to each IROFS based on industry accepted values, past experience, engineering judgment, analytical data, and/or any other applicable information.

Although the assigned index is qualitative in nature, the "-2" index in Table 5-4 does correlate to nominal failure probability or rates as published in "Savannah River Site Human Error Data Base Development for Nonreactor Nuclear Facilities." However, the data presented in the Savannah River site database does not represent failure rates for IROFS protected by management measures as required in 10 CFR 70, Subpart H. The Savannah River site database Administrative Controls are not bounded by the additional scrutiny afforded by

assigning the administrative control as an IROFS with management measures to ensure the IROFS is reliable and available to perform its intended function. With such scrutiny, as required by 10 CFR 70, Subpart H, a –2 index is assigned as the index representing an IROFS administrative control in Table 5-4 (protected by a trained operator performing a routine task with an approved procedure). This value was determined by taking the midpoint of the nominal and high administrative control failure probability or rates from the Savannah River site database. Accordingly, a –1 index is assigned for a trained operator performing a non-routine task with an approved procedure.

The Savannah River Site Human Error Data Base Development document is applicable to NFS in that the Savannah River Site provides for operations such as storage, dissolution, and downblending of source terms similar to NFS. In addition, the database is particularly focused to non-reactor nuclear facilities.

The values in Table 5-4 are a minimum guide for index assignment, and if applicable, NFS may choose to assign additional conservatism to the indices used in Section 4.3, thereby assigning additional safety margin to the IROFS.

A special case of accident scenario is when a failure of an IROFS is the initiating event. In these scenarios, an Initiating Event Failure Frequency Index is not assigned. Instead, the IROFS Effectiveness of Protection Index is selected for the IROFS from Table 5-4. The IROFS that triggers the accident scenario is assigned a Duration Index as specified in Table 5-5. The duration Index is a qualitative measurement of the time the system is vulnerable to the failure of a second IROFS when the second IROFS prevents a credible High or Intermediate consequence accident sequence from occurring. As such, the accident sequence is also evaluated by reversing the sequence of failure to determine the system vulnerability based on failing the second IROFS first.

Setpoints for IROFS interlocks and alarms shall be selected using conservative engineering analyses which account for safety limits, instrument and system accuracies, response time, instrument drift, manufacturer's data and operating experience. The analysis for each safety setpoint shall be a formal calculation and shall be documented for each applicable IROFS. Calibration and functional test frequencies should also consider data used in the setpoint determination.

Specifications for procurement of devices used as IROFS take these performance criteria into account and ensure that the device (and the whole IROFS) is reliable and available.

Table 5-4 IROFS Effectiveness of Protection Index

Effectiveness of Protection Index	Type of IROFS**
-4* ***	Protected by an exceptionally robust inspected passive engineered control (PEC). Exceptionally Robust Management Measures to ensure availability.
-3*	Protected by an inspected single PEC or exceptionally robust functionally tested AEC with a trained operator backup. Adequate Management Measures to ensure availability.
-2*	Protected by a single functionally tested AEC. Protected by a trained operator performing a routine task with an approved procedure, an enhanced administrative control, or an administrative control with large margin. Adequate Management Measures to ensure availability.
-1	Protected by a single administrative control or a trained operator performing a nonroutine task with an approved procedure.
0	No protection

*Indices less than (more negative than) "-1" should not be assigned to IROFS unless the configuration management, auditing and other management measures are of high quality, because without these measures, the IROFS may be changed or not maintained.

**The index value assigned to an IROFS of a given type may be one value higher or lower than the value given. Criteria justifying assignment of the lower value should be given in the narrative describing ISA methods. Exceptions require individual justification.

***Rarely can be justified by evidence. Further, most types of single IROFS have been observed to fail.

Preventative and Mitigative IROFS Failure Indices for all credible High or Intermediate consequence accident scenarios are assigned and documented in Section 4.3 tables.

Table 5-5: Failure Duration Index Numbers

Duration Index Numbers	Avg. Failure Duration	Duration in Years	Comments
1	More than 3 years	10	
0	1 year	1	
-1	1 month	0.1	Formal Monitoring to justify indices less than "-1
-2	A few days	0.01	
-3	8 hours	0.001	
-4	1 hour	10^{-4}	
-5	5 minutes	10^{-5}	

Failure Duration Indices for all credible High or Intermediate consequence accident scenarios are assigned and documented in Section 4.3 tables.

Event Likelihood

To demonstrate compliance with 10 CFR 70.61, all credible accident scenarios upon application of IROFS require a likelihood determination. A Controlled Likelihood and an Uncontrolled Likelihood are calculated to demonstrate the

relative importance of the IROFS in preventing or mitigating the accident sequence to meet the performance requirements. A Controlled Likelihood Index T is calculated by summing the Initiating Event Failure Frequency Index to the IROFS Failure Index(s). If the initiating event is an IROFS failure, then the Controlled Likelihood Index T is calculated by summing the IROFS Failure Indexes and the Failure Duration Index. An Uncontrolled Likelihood Index T is calculated by using the Initiating Event Failure Frequency Index or the IROFS Failure Index as applicable. Controlled and Uncontrolled Likelihood Categories are then assigned from **Table 5-6** based on the respective Likelihood Index.

Table 5-6 Total Risk Likelihood Category

Likelihood Category	Likelihood Index T (=sum of index numbers)
1	$T \leq -4$
2	$-4 < T \leq -3$
3	$T > -3$

Controlled and Uncontrolled Likelihood Indices for all credible High or Intermediate consequence accident scenarios are assigned and documented in Section 4.3 tables. Controlled and Uncontrolled Likelihood Categories are assigned and documented in Section 4.3 tables.

Resultant Risk Category

The qualitative values for the Likelihood and Consequence Categories are plotted on the Risk Matrix (**Table 5-7**) for categorization of Controlled and Uncontrolled Risk. The Controlled Risk is calculated by multiplying the Consequence Category by the Controlled Likelihood Category. The Uncontrolled Risk is calculated by multiplying the Consequence Category by the Uncontrolled Likelihood Category. 10 CFR 70.61 performance requirement acceptability is determined by comparing the Controlled Risk to **Table 5-7**. As shown in **Table 5-7**, a risk greater than 4 is unacceptable and does not meet the 10 CFR 70.61 performance requirements.

Table 5-7: RISK MATRIX

	Likelihood Cat. 1 Highly Unlikely	Likelihood Cat. 2 Unlikely	Likelihood Cat. 3 Not Unlikely
Consequence Cat. 3 High	3 Acceptable	6 Unacceptable	9 Unacceptable
Consequence Cat. 2 Intermediate	2 Acceptable	4 Acceptable	6 Unacceptable
Consequence Cat. 1 Low	1 Acceptable	2 Acceptable	3 Acceptable

Controlled and Uncontrolled Risk for all credible High or Intermediate consequence accident scenarios are assigned and documented in Section 4.3 tables.

5.2.4 IROFS List

Once the proposed IROFS have been evaluated through Risk Assessment, a final set of IROFS are generated. The final set of IROFS have been determined acceptable based on meeting the 10 CFR 70.61 risk criteria (Highly Unlikely or Unlikely risk). The IROFS list is included in Section 6 of this report.

5.2.5 Management Measures

The final step of defining Management Measures for each IROFS is explained in detail in Section 4.4 of this report.

6.0 LIST OF IROFS FOR THE BPF

6.1 IROFS AND MANAGEMENT MEASURES FOR BPF

Tables 6-1 through 6-6 define the IROFS credited in the Section 4 Risk tables with reducing the likelihood of postulated Intermediate and High consequence events to unlikely or highly unlikely levels as required by 10 CFR 70.61.

The information provided in the IROFS tables form the basis for development of procedures, postings, controlled equipment lists, and other IROFS implementing documents. The development of Management Measures is further defined in Section 4.4 of the ISA Summary.

6.1.1 Natural Phenomena and Configuration Control IROFS

Table 6-7 defines IROFS to address seismic and high wind natural phenomena events, as well as certain equipment required to be maintained in accordance with specific design requirements credited in Nuclear Criticality Safety Evaluations.

Item PREP-C in Table 6-7 represents certain equipment (e.g., columns) for which no failure mode leads to a high consequence accident, but that if improperly modified or replaced, could allow such an accident to occur. Such equipment is generically classified as items relied on for safety (IROFS) in accordance with 10 CFR 70.4. These types of equipment are not individually identified herein. They will be maintained in their safe configuration using the configuration control management measure, as implemented by NFS Management Measures Program specified in Chapter 2.12 of SNM-124. This program requires tracking of changes to important equipment dimensions and characteristics relied on for safety, and provides comprehensive controls to ensure that safe characteristics are maintained.

For the purpose of maintaining records of configuration control failures, this type of equipment will be aggregated into generic categories and records will be maintained for each of these generic categories in the problem identification, resolution and correction system.

Identification of specific structures, systems or components, designated as IROFS, that will be maintained within their safe configuration will be based on the following attributes:

- some characteristic that is relied on for double contingency, which will not change with time as a result of accidents identified in the ISA; or
- the control is supplemented by one or more controls as one leg of the double contingency principle.

These structures, systems or components are considered passive engineering controls for the purpose of assigning risk indices and meeting the performance requirements specified in 10 CFR 70.61 for high consequence accidents.

Table 6-1
Criticality Safety IROFS

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
Uranium Metal Dissolution System					
[redacted]	≤	4.1.1, 4.1.5, 4.1.15, 4.1.17	High Criticality	X	
[redacted]		4.1.1, 4.1.5, 4.1.26	High Criticality	X	
[redacted]		4.1.1, 4.1.5, 4.1.25, 4.1.26	High Criticality	X	
[redacted]		4.1.1, 4.1.2	High Criticality	X	
[redacted]		4.1.1, 4.1.2	High Criticality	X	
[redacted]		4.1.7	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.7	High Criticality	X	
[redacted]		4.1.7	High Criticality	X	
[redacted]		4.1.8, 4.1.10, 4.1.14, 4.1.21	High Criticality	X	
[redacted]		4.1.8	High Criticality	X	
[redacted]		4.1.7, 4.1.22	High Criticality	X	
[redacted]		4.1.8	High Criticality	X	
[redacted] And [redacted]		4.1.7, 4.1.9	High Criticality	X	
[redacted] And [redacted]		4.1.7, 4.1.9	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.10	High Criticality	X	
[redacted]		4.1.19, 4.1.20	High Criticality	X	
[redacted]		4.1.14	High Criticality	X	
[redacted]		4.1.15, 4.1.19	High Criticality	X	
[redacted]		4.1.15, 4.1.17, 4.1.19	High Criticality	X	
[redacted]		4.1.17	High Criticality	X	
[redacted]		4.1.20	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.21;4.1.28	High Criticality	X	
[redacted]		4.1.7;4.1.22	High Criticality	X	
[redacted]		4.1.22	High Criticality	X	
[redacted]		4.1.25	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.28	High Criticality	X	
[redacted]		4.1.29	High Criticality	X	
[redacted]		4.1.29	High Criticality	X	
Uranium Metal Sampling Area					
[redacted]		BMS-39.1, Too much U in ENCLOS-3E03.	High Criticality	X	
ENCLOS-3E03		BMS-39.1, Too much U in ENCLOS-3E03.	High Criticality	X	
Uranium/Aluminum Dissolution System					
[redacted]		BUA-Backflow-1 BUA-Backflow-2 BUA-Backflow-3 BUA-Backflow-4 BUA-Backflow-5 BUA-CoolingWaterSupply-1	High Criticality	X	
[redacted]		BUA-Backflow-1	High Criticality	X	
[redacted]		BUA-Backflow-2	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		BUA-Backflow-3	High Criticality	X	
[redacted]		BUA-Backflow-4	High Criticality	X	
[redacted]		BUA-Backflow-5	High Criticality	X	
[redacted]		BUA-Centrifuge-1 BUA-Spill-1	High Criticality	X	
[redacted]		BUA-Centrifuge-1 BUA-Spill-1	High Criticality	X	
[redacted]	1.	BUA-Enclosure-1 BUA-Spill-1	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		BUA-Enclosure-1 BUA-Spill-1 BUA-FilterEnclosure-1	High Criticality	X	
[redacted]		BUA-FilterEnclosure-1	High Criticality	X	
[redacted]	1.	BUA-FilterEnclosure-1	High Criticality	X	
[redacted]		BUA-Spill-1 BUA-Spill-2	High Criticality	X	
[redacted]		BUA-Spill-1 BUA-Spill-2	High Criticality	X	
[redacted]		BUA-Enclosure-2 BUA-Enclosure-3	High Criticality	X	
[redacted]		BUA-Enclosure-2 BUA-Enclosure-3	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		BUA-Enclosure-3	High Criticality	X	
[redacted]		BUA-Enclosure-3	High Criticality	X	
[redacted]		BUA-CoolingWaterSupply-1	High Criticality	X	
[redacted]		BUA-Centrifuge-1	High Criticality		
[redacted]		BUA-Spill-2	High Criticality		
High Security Storage Area (Racks)					
[redacted]		4.1.1, 4.1.9	High Criticality	X	
[redacted]		4.1.1	High Criticality	X	
[redacted]	≤	4.1.6	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.2	High Criticality	X	
[redacted]		4.1.2	High Criticality	X	
[redacted]		4.1.5	High Criticality	X	
[redacted]		4.1.5	High Criticality	X	
[redacted]		4.1.8	High Criticality	X	
[redacted]		4.1.8	High Criticality	X	
[redacted]		4.1.9	High Criticality	X	
[redacted]		4.1.9	High Criticality	X	
[redacted]		4.1.9	High Criticality	X	
[redacted]		4.1.1	High Criticality		

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.1	High Criticality		
Solvent Extraction					
[redacted]		BSX-Backflow-1 BSX-Backflow-2 BSX-Backflow-3 BSX-Backflow-4 BSX-Backflow-5 BSX-CoolingWaterSystem-1	High Criticality	X	
[redacted]		BSX-Backflow-1	High Criticality	X	
[redacted]		BSX-Backflow-2	High Criticality	X	
[redacted]		BSX-Backflow-3	High Criticality	X	
[redacted]		BSX-Backflow-4	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		BSX-Backflow-5	High Criticality	X	
[redacted]		BSX-Drybox-1	High Criticality	X	
[redacted]		BSX-Drybox-1	High Criticality	X	
[redacted]		BSX-Spill-1 BSX-Spill-2A BSX-Spill-2B	High Criticality	X	
[redacted]		BSX-Spill-1 BSX-Spill-2A BSX-Spill-2B	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		BSX-Drybox-2A	High Criticality	X	
[redacted]		BSX-Drybox-2A BSX-Drybox-2B	High Criticality	X	
[redacted]		BSX-Drybox-2A BSX-Drybox-2B	High Criticality	X	
[redacted]		BSX-Drybox-2B	High Criticality	X	
[redacted]		BSX-CoolingWaterSystem-1	High Criticality	X	
[redacted]		BSX-BuildingWalls-1	High Criticality	X	
Downblending System					
[redacted]		4.1.1.1, 4.1.1.2	High Criticality	X	
[redacted]		4.1.1.1, 4.1.1.3, 4.1.1.5	High Criticality	X	
[redacted]		4.1.1.2	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.1.1, 4.1.1.4	High Criticality	X	
[redacted]		4.1.1.1, 4.1.1.4	High Criticality	X	
[redacted]		4.1.1.5	High Criticality	X	
[redacted]		4.1.1.8	High Criticality	X	
[redacted]		4.1.1.8	High Criticality	X	
[redacted]		4.1.2.1, 4.1.3.1, 4.1.3.2, 4.1.3.3	High Criticality	X	
[redacted]		4.1.3.1	High Criticality	X	
[redacted]		4.1.3.2	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.1.3	High Criticality	X	
[redacted]		4.1.1.6; 4.1.4.1	High Criticality	X	
[redacted]		4.1.1.6	High Criticality	X	
[redacted]		4.1.1.7; 4.1.4.2	High Criticality	X	
[redacted]		4.1.1.7; 4.1.4.2	High Criticality	X	
[redacted]		4.1.2.1; 4.1.2.2; 4.1.2.3	High Criticality	X	
[redacted]		4.1.2.1; 4.1.2.2	High Criticality	X	
[redacted]		4.1.2.3			
Liquid Waste Discard System					
[redacted]		Scenario A	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		Scenario A Scenario B	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		Scenario A	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		Scenario B	High Criticality	X	
Process Ventilation					
[redacted]		4:1.1;4:1.2;4.1:3	High Criticality	X	

IROFS		Hazard Analysis and Risk Assessment		Management Measures Level	
Identification	Safety Function Description	Accident Sequence	Consequence Level	A	B
[redacted]		4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6	High Criticality	X	
[redacted]		4.1.1, 4.1.4, 4.1.5, 4.1.6	High Criticality	X	
[redacted]		4.1.3	High Criticality	X	
[redacted]		4.1.3	High Criticality	X	

Table 6-2
Chemical Safety IROFS - Worker

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
Active Engineered Controls											
[redacted]		UND6.39	UND6.41						High Chemical	X	
[redacted]		1UMD1.7	2UMD2.7	1UMD1.139	2UMD2.139				High Chemical	X	
[redacted]		SXFC9.5	1PE12.43	1PE12.45	1PRS17.18	2PRS18.8	SXSC19.3	1SXCM23.4	High Chemical	X	
[redacted]		1UALS33.98	2UALS34.91						High Chemical	X	
[redacted]		PS45.118							High Chemical	X	

Identification	Safety Function Description	What-If							Consequence Level	Measurement Measures Level	
										A	B
Passive Engineered Controls											
[redacted]		1UMD1.4	2UMD2.4	UND6.43	SXFC9.15	1PE12.47	1PRS17.21	2PRS18.8	High Chemical	X	
		SXSC19.8	1SXCM23.6	1UALS33.55	2UALS34.52	UTD40.17A	CMST38.25	CMST38.26			
[redacted]		1UMD1.4	2UMD2.4	UND6.43	SXFC9.15	1PE12.47	1PRS17.21	2PRS18.8	High Chemical	X	
		SXSC19.8	1SXCM23.6	1UALS33.55	2UALS34.52	UTD40.17A	CMST38.25	CMST38.26			
[redacted]		UTD40.17B							High Chemical	X	
[redacted]		UTD40.17B							High Chemical	X	
[redacted]		UND6.291	UND6.224	UND6.225					High Chemical	X	
[redacted]		CMST38.1	CMST38.30	CMST38.39					Intermediate Chemical		X
[redacted]		CMST38.5	CMST38.6						Intermediate Chemical		X
[redacted]		CMST38.28	CMST38.39	CMST38.51					Intermediate Chemical		X
[redacted]		CD27.21	CD27.26						Intermediate Chemical		X
[redacted]		CD27.1							Intermediate Chemical		X
[redacted]		PS45.134							Intermediate Chemical		X
[redacted]		PV45.132							Intermediate Chemical		X

Identification	Safety Function Description	What-If							Consequence Level	Measurement Measures Level	
										A	B
Administrative/Enhanced Administrative Controls											
[redacted]		1UMD1.4	2UMD2.4	UND6.43	SXFC9.15	1PE12.47	1PRS17.21	2PRS18.8	High Chemical	X	
		SXSC19.8	1SXCM23.6	1UALS33.55	2UALS34.52	UTD40.17A	UTD40.17B	CMST38.25			
		CMST38.26									
[redacted]		1UMD1.4	2UMD2.4	UND6.43	SXFC9.15	1PE12.47	1PRS17.21	2PRS18.8	High Chemical	X	
		SXSC19.8	1SXCM23.6	1UALS33.55	2UALS34.52	UTD40.17A	UTD40.17B	CMST38.25			
		CMST38.26									
[redacted]		CMST38.52							Intermediate Chemical		X
[redacted]		UTD40.17B	CMST38.52						High Chemical	X	
[redacted]		UTD40.17B							High Chemical	X	
[redacted]		UTD40.17B							High Chemical	X	
[redacted]		UND6.39	UND6.41						High Chemical	X	
[redacted]		UND6.291	UND6.224	UND6.225					High Chemical	X	
[redacted]		UND6.291	UND6.224	UND6.225					High Chemical	X	
[redacted]		1UMD1.7	1UMD1.139	2UMD2.7	2UMD2.139				High Chemical	X	

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		SXFC9.5	1PE12.45	1PRS17.18	2PRS18.8	SXSC19.3	1SXCM23.4		High Chemical	X	
[redacted]		1PE12.43	1PE12.45	1PRS17.18					High Chemical	X	
[redacted]		1UALS33.98	2UALS34.9I						High Chemical	X	
[redacted]		CMST38.52							Intermediate Chemical		X
[redacted]		CMST38.52							Intermediate Chemical		X
[redacted]		PS45.118							High Chemical	X	
[redacted]		PS45.118							High Chemical	X	
[redacted]		PS45.118							High Chemical	X	
[redacted]		PS45.120							Intermediate Chemical		X
[redacted]		PS45.120							Intermediate Chemical		X

Identification	Safety Function Description	What-ifs							Consequence Level	Measurement Measures Level	
										A	B
Chemical Toxicity IROFS (Soluble Uranium)											
Active Engineering Controls											
None											
Passive Engineering Controls											
[redacted]		UNT7.3	UNT7.53						High Soluble U	X	
[redacted]		UNT7.54							High Soluble U	X	
[redacted]		UNT7.3	UNT7.54						High Soluble U	X	
Administrative/Enhanced Administrative Controls											
[redacted]		UNT7.3							High Soluble U	X	

*These IROFS also support a High consequence event and therefore are assigned a High management measure level.

Table 6-3
Radiological Safety IROFS - Worker

Identification	Safety Function Description	What-ifs							Consequence Level	Measurement Measures Level	
										A	B
Active Engineered Controls											
None											
Passive Engineered Controls											
None											
Administrative/Enhanced Administrative Controls											
None											

Table 6-4
Environmental Chemical Safety IROFS - Public

Identification	Safety Function Description	What-Ifs			Consequence Level	Measurement Measures Level	
						A	B
Active Engineered Controls							
[redacted]		UND6.39			High Env. Chem	X	
[redacted]		UND6.43			High Env. Chem	X	
Passive Engineered Controls							
[redacted]		UND6.39	UND6.43	UND6.46	High Env. Chem	X	
[redacted]		UTD40.17B			High Env. Chem	X	
[redacted]		UTD40.17B			High Env. Chem	X	
Administrative/Enhanced Administrative Controls							
[redacted]		UTD40.17B			High Env. Chem	X	
[redacted]		UTD40.17B			High Env. Chem	X	
[redacted]		CMST38.52			Intermediate Env. Chem		X
[redacted]		UTD40.17B	CMST38.52		High Env. Chem	X	
[redacted]		UTD40.17B			High Env. Chem	X	
[redacted]		UTD40.17B			High Env. Chem	X	
[redacted]		UND6.46			High Env. Chem	X	

Identification	Safety Function Description	What-If			Consequence Level	Measurement Measures Level	
						A	B
[redacted]		CMST38.52			Intermediate Env. Chem		X
[redacted]		CMST38.52			Intermediate Env. Chem		X

Table 6-5
Environmental Radiological Safety IROFS - Public

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
Active Engineered Controls											
None											
Passive Engineered Controls											
[redacted]		UDB5.78	UDB5.80	UDB5.83	UDB5.84	UDB5.88	UDB5.91	UDB5.93	Intermediate Envl Radiological	X*	
		UDB5.97	UDB5.100	UDB5.103	UDB5.116	UDB5.129	UDB5.138	UNT7.5			
		UNT7.8	UNT7.12	UNT7.13	UNT7.17	UNT7.19	UNT7.22	UNT7.45			
		1UMD1:147	2UMD2:147	1UMD1:148	2UMD2:148	1UMD1:156	2UMD2:156	3DT3:1			
		3DT3:2	3DT3:3	3D3:11	3DT3:33	7DT4:1	7DT4:2	7DT4:3			
		7DT4:4	7DT4:5	7DT4.6	7DT4:17	7DT4.45	UAEAC37:3	UAEAC37:38			
		UDB5:14	UDB5:16	UDB5:18	UDB5:20	UDB5:22	UDB5:24	UDB5:26			
		UDB5.28	UDB5.30	UDB5:32	UMM8:12						
[redacted]		UNT7.38A							Intermediate Envl Radiological		X
[redacted]		UNT7.38B							Intermediate Envl Radiological		X
[redacted]		UNT7.38B							Intermediate Envl Radiological		X
[redacted]		UNT7:3	UNT7.53						Intermediate Envl Radiological	X*	
[redacted]		UNT7.37	UNT7.39	UNT7.42	UNT7.45				Intermediate Envl Radiological		X
Administrative/Enhanced Administrative Controls											
[redacted]		UNT7.38B							Intermediate Envl Radiological	X*	

Identification	Safety Function Description	What-If							Consequence Level	Measurement Measures Level	
										W	B
[redacted]		UNT7.38B							Intermediate Env/ Radiological	X*	
[redacted]		UNT7.39	UNT7.44						Intermediate Env/ Radiological	X*	
[redacted]		UNT7.39	UNT7.44						Intermediate Env/ Radiological	X*	
[redacted]		UNT7.38B							Intermediate Env/ Radiological	X*	
[redacted]		UNT7.31							Intermediate Env/ Radiological		X
[redacted]		UNT7.31							Intermediate Env/ Radiological		X
[redacted]		UNT7.39							Intermediate Env/ Radiological		X

*These IROFS also support a High consequence event and therefore are assigned a High management measure level.

Table 6-6
Fire Safety IROFS

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
Active Engineering Controls											
[redacted]		1PX10.2	1PX10.55	1PX10.57	1PX10.63				High Red Oil	X	
[redacted]		1PX10.2	1PX10.55	1PX10.57	1PX10.63				High Red Oil	X	
[redacted]		1PX10.2	1PX10.55	1PX10.57	1PX10.63				High Red Oil	X	
[redacted]		1PX10.2	1PX10.55	1PX10.57	1PX10.63				High Red Oil	X	
[redacted]		2PSX13.35	2PSX13.37	2PSX13.41	2PSX13.90				High Red Oil	X	
[redacted]		2PSX13.35	2PSX13.37	2PSX13.41	2PSX13.71	2PSX13.90			High Red Oil	X	
[redacted]		2PSX13.35	2PSX13.37	2PSX13.41	2PSX13.71	2PSX13.90			High Red Oil	X	
[redacted]		2PSX13.35	2PSX13.37	2PSX13.41	2PSX13.71	2PSX13.90			High Red Oil	X	

Identification	Safety Function Description	Whatifs							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		1UALD29.25	1UALD29.26	1UALD29.30	1UALD29.23	1UALD29.78	1UALD29.80	1UALD29.88	High Hydrogen Explosion	X	
		CMST38.19	CMST38.34								
[redacted]		1UALD29.25	1UALD29.26	1UALD29.30	1UALD29.23	1UALD29.78	1UALD29.80	1UALD29.88	High Hydrogen Explosion	X	
		CMST38.19	CMST38.34								
[redacted]		2UALD30.25	2UALD30.26	2UALD30.30	2UALD30.23	2UALD30.78	2UALD30.80	2UALD30.88	High Hydrogen Explosion	X	
		CMST38.18	CMST38.33								

Identification	Safety Function Description	What-If							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		2UALD30.25	2UALD30.26	2UALD30.30	2UALD30.23	2UALD30.78	2UALD30.80	2UALD30.88	High Hydrogen Explosion	X	
		CMST38.18	CMST38.33								
[redacted]		3UALD31.25	3UALD31.26	3UALD31.30	3UALD31.23	3UALD31.78	3UALD31.80	3UALD31.88	High Hydrogen Explosion	X	
		CMST38.17	CMST38.32								
[redacted]		3UALD31.25	3UALD31.26	3UALD31.30	3UALD31.23	3UALD31.78	3UALD31.80	3UALD31.88	High Hydrogen Explosion	X	
		CMST38.17	CMST38.32								

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		4UALD32.25	4UALD32.26	4UALD32.30	4UALD32.23	4UALD32.78	4UALD32.80	4UALD32.88	High Hydrogen Explosion	X	
		CMST38.16	CMST38.31								
[redacted]		4UALD32.25	4UALD32.26	4UALD32.30	4UALD32.23	4UALD32.78	4UALD32.80	4UALD32.88	High Hydrogen Explosion	X	
		CMST38.16	CMST38.31								
[redacted]		1UALD29.25	1UALD29.26	1UALD29.30	1UALD29.23	1UALD29.70	1UALD29.78	1UALD29.80	High Hydrogen Explosion	X	
		1UALD29.84	1CMST38.19	1CMST38.34	PV443						

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		2UALD30.25	2UALD30.26	2UALD30.30	2UALD20.23	2UALD30.70	2UALD30.78	2UALD30.80	High Hydrogen Explosion	X	
		2UALS30.84	1CMST38.18	1CMST38.33	PV44.3						
[redacted]		3UALD31.25	3UALD31.26	3UALD31.30	3UALD30.23	3UALD31.70	3UALD31.78	3UALD31.80	High Hydrogen Explosion	X	
		3UALD31.84	1CMST38.17	1CMST38.32	PV44.3						
[redacted]		4UALD32.25	4UALD32.26	4UALD32.30	4UALD32.23	4UALD32.70	4UALD32.78	4UALD32.80	High Hydrogen Explosion	X	
		4UALD32.84	1CMST38.16	1CMST38.31	PV44.3						

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		CMST38.20	CMST38.34	CMST38.36	CMST38.47				High Hydrogen Explosion	X	
[redacted]		CMST38.20	CMST38.33	CMST38.36	CMST38.47				High Hydrogen Explosion	X	
[redacted]		CMST38.20	CMST38.32	CMST38.36	CMST38.47				High Hydrogen Explosion	X	
[redacted]		CMST38.20	CMST38.31	CMST38.36	CMST38.47				High Hydrogen Explosion	X	
Passive Engineering Controls											
[redacted]		2PSX13.35	2PSX13.71	2PSX13.90					High Red Oil	X	
[redacted]		1PE12.88	1PE12.90	1PE12.92	1PE12.185				High Red Oil	X	

Identification	Safety Function Description	What-Ifs							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		1PE12.88	1PE12.90	1PE12.92	1PE12.185				High Red Oil	X	
[redacted]		1PE12.186							High Red Oil	X	
[redacted]		1PE12.186							High Red Oil	X	
[redacted]		1PE12.187							High Red Oil	X	

Identification	Safety Function Description	What-If							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		2PE15.82	2PE15.84	2PE15.86	2PE15:155				High Red Oil	X	
[redacted]		2PE15.82	2PE15.84	2PE15.86	2PE15:155				High Red Oil	X	
[redacted]		2PE15:156							High Red Oil	X	

Identification	Safety Function Description	What-Ifs							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		2PE15.156							High Red Oil	X	
[redacted]		2PE15.157							High Red Oil	X	
[redacted]									Fire Bound	X	
[redacted]									Fire Bound	X	
[redacted]									Fire Bound	X	
[redacted]									Fire Bound	X	
[redacted]									Fire Bound	X	
[redacted]		1UALD29.45	2UALD30.45	3UALD31.45	4UALD32.45				High Hydrogen Explosion	X	
[redacted]		1UALD29.48	1UALD29.49	1UALD29.66					High Hydrogen Explosion	X	
BUA-33		2UALD30.48	2UALD30.49	2UALD30.66					High Hydrogen	X	

Identification	Safety Function Description	What-ifs							Consequence Level	Measurement Measures Level	
										A	B
									Explosion		
[redacted]		3UALD31.48	3UALD31.49	3UALD31.66					High Hydrogen Explosion	X	
[redacted]		4UALD32.48	4UALD32.49	4UALD32.66					High Hydrogen Explosion	X	
Administrative/Enhanced Administrative Controls											
[redacted]		1PE12.187							High Red Oil	X	
[redacted]		2PE15.157							High Red Oil	X	
[redacted]		1UALD29.25	1UALD29.26	1UALD29.30	1UALD29.23	1UALD29.49	1UALD29.78	1UALD29.80	High Hydrogen Explosion	X	

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		2UALD30.25	2UALD30.26	2UALD30.30	2UALD30.23	2UALD30.49	2UALD30.78	2UALD30.80	High Hydrogen Explosion	X	
[redacted]		3UALD31.25	3UALD31.26	3UALD31.30	3UALD31.23	3UALD31.49	3UALD31.78	3UALD31.80	High Hydrogen Explosion	X	
[redacted]		4UALD32.25	4UALD32.26	4UALD32.30	4UALD32.23	4UALD32.49	4UALD32.78	4UALD32.80	High Hydrogen Explosion	X	

Table 6-7
Natural Phenomena and Configuration Control IROFS

Identification	Safety Function Description	Accident Sequence	Consequence Level	Management Measures	
				A	B
[redacted]	Building 333 (excluding solvent extraction) is designed to meet the seismic load resistance per the option allowed under the 1999 Standard Building Code (ASCE 7-98)	Earthquake	High	X	
[redacted]	Building 333 (excluding solvent extraction) is designed to meet the wind load resistance as specified in the 1999 Standard Building Code	High Wind	High	X	
[redacted]	Structures, systems, components, such as favorable geometry columns, dikes, floors, and piping that require configuration control for criticality safety	Configuration modification	High Criticality	X	

6.2 BASELINE DESIGN CRITERIA FOR CREDITED IROFS

The Baseline Design Criteria specified in 10 CFR 70.64 are addressed for the BPF through programmatic evaluations or specifically as part of the engineering design review process. Programmatic elements such as the QA Program, Fire Hazards Analysis, NFS Emergency Plan and Nuclear Criticality Safety Evaluations provide overall consideration of the baseline design criteria for the BPF. For other design criteria such as seismic, environmental, dynamic effects, chemical protection, utilities, and instrumentation / controls, each criteria is considered individually for each IROFS as part of the design/review process.

An explanation is provided below to address each of the Baseline Design Criteria for the BPF. In addition, a checklist has been developed for engineering to confirm and document that each of the criteria were adequately addressed for each specific IROFS. **Tables 6-8 and 6-9** provide an example of the methodology engineering will use to confirm and document the detailed review of each IROFS for baseline design criteria. Once completed, this checklist and supporting documentation will be maintained in the ISA file for the BPF.

Quality Standards and Records

The design must be developed and implemented in accordance with management measures to provide adequate assurance that IROFS will be available and reliable to perform their function when needed. Appropriate records of these items must be maintained by or under the control of the licensee throughout the life of the facility.

As stated, 10 CFR 70.64(a)(1) requires the use of appropriate management measures to assure the availability and reliability of items relied on for safety. The management measures listed in Section 4.4 have been programmatically used by NFS since 1996 to successfully maintain items relied on for safety. The successful implementation of this management measure program is verified by NFS through regularly scheduled internal quality assurance audits and has been rigorously scrutinized by the NRC since its inception. As required by the latter part of 70.64(a)(1), appropriate program records have been and will continue to be maintained by NFS. Concerning equipment and equipment specifications, NFS defines and confirms upon procurement the applicable design specifications prior to materials and equipment use. When standard off-the-shelf components are identified as items relied on for safety, the appropriate management measures (e.g., functional testing, inspections, calibration) are implemented to assure their availability and reliability.

Functional testing of IROFS is scheduled, performed, tracked and documented for review, per NFS' Safety Related Equipment Program. Functional testing is performed to ensure that the IROFS is reliable and available to perform its

intended safety function. Functional testing is conducted using approved procedures with process compensatory measures being applied while the test is being performed. The functional testing periodicity is established by risk assessment and operational safety discipline evaluations.

Natural Phenomena Hazards

The design must provide for adequate protection against natural phenomena with consideration of the most severe documented historical events for the site.

Natural phenomena are discussed in detail in Section 1 of this ISA Summary. Baseline Design Natural Phenomena Events have design thresholds applied to establish a defined protection envelope to prevent unsafe conditions arising from natural phenomena events. The BPF facility baseline design threshold for each natural phenomena event is as follows:

Seismic – Building 333 was built in approximately 1991 to the 1988 Edition of the Standard Building Code. Seismic loading was according to this edition of the SBC. It has since been determined that the internal components, as a minimum, were designed and constructed commensurate with the 1999 Standard Building Code requirements, which corresponds to a threshold return probability of 2E-3/yr. Facility IROFS have been assigned to prevent a high consequence event that may result from a seismic event within the specified threshold envelope. Refer to the Section 6.1 IROFS tables for specific controls.

Additions to the building for the BPF were built to the 1999 SBC with the option to use ASCE-7/98 (Minimum Design Load for Buildings and other Structures, American Society of Civil Engineers, 2000) for seismic and NFS Seismic design criteria. The threshold return probability for ASCE-7/98 is 4E-4/yr. NFS had the design and construction reviewed to the current standards and it meets the present 1999 Edition of the Standard Building Code.

High Winds – Building 333 was built in approximately 1991 to the 1988 Edition of the Standard Building Code. Wind loading was established through ANSI A58.1, 1982 edition. The ANSI Standard was changed later to the ASCE-7 standard. It is designed and constructed to withstand basic sustained wind speeds up to 70 miles per hour as specified in Section 1606 of the 1999 Standard Building Code. Facility IROFS are assigned to prevent a high consequence event that may result from high winds within the specified threshold envelope. Refer to Section 6.1 tables for IROFS description.

Flooding: The BPF is located above the 100-year flood plain base flood elevation threshold. As such, there is no credible accident scenario that could result in a flood of the facility.

Lightning: Lightning protection is installed in the BPF per the applicable portions of NFPA 780. There are no credible accident scenarios that result in an intermediate or high consequence event as a result of a lightning strike.

Tornado: As discussed in Section 1.3.3, there are no credible accident scenarios that result in an intermediate or high consequence event as a result of a tornado strike on the BPF.

Code compliance in these cases is ensured by:

- Design drawings and specifications call out applicable code requirements.
- Construction/installation will be verified to meet the design specifications through the use of reputable, licensed contractors who have many years of experience with industrial and commercial construction projects. Inspections have been conducted at regular intervals by the professional engineers and architects who designed those portions.
- Construction progress is reviewed routinely by qualified NFS project engineers and construction coordinators to ensure construction is performed as specified in the design drawings.
- Walkdowns of the facility will be conducted as part of the NFS Operational Readiness Review process to ensure the building construction and equipment installation was completed properly.
- Internally Authorized Change (IAC) reviews and inspections will document a Final Installation Review and Startup Report as part of the Configuration Management Program. The IAC will have signoff/checklists that document the as-built verifications and that the installations meet code requirements, where applicable. Any future change to the facility, structures, processes, systems, equipment, components, computer programs, procedures, etc. will also be evaluated per License Condition S-25 criteria. The change will be reviewed against the approved safety bases, to include the Standard Building Code and other applicable codes.

Fire Protection

The design must provide for adequate protection against fires and explosions.

The fire protection features and systems for the BPF are defined in Section 2 of this report. These features are based on a comprehensive FHA performed for the BPF as part of the ISA process. Section 3 of this report identifies the fire hazards

and protection systems for each process of BPF operations. The fire protection systems and features defined in Sections 2 and 3, along with those specifically defined as IROFS, will be maintained and verified with appropriate management measures to provide adequate fire protection for BPF operations.

Environmental and Dynamic Effects

The BPF facility is designed to minimize problems from variations (both normal and from credible upsets) in the ambient and process conditions under which the IROFS equipment is expected to operate. Consideration in the design of the facility and equipment is given to the following to prevent loss of safety functions:

- Protection of piping and vessels from vehicles and forklifts.
- Protection of fittings from external impact.
- Corrosion protection.
- Vibration from pumps/fans etc.
- Water discharge from sprinkler systems (or other splash).
- Weather
- Other facility siting factors including the railway, air traffic patterns, and nearby commercial facilities.

As such, IROFS will be qualified to demonstrate that they can perform their safety functions under the environmental and dynamic service conditions in which they will be required to function and for the length of time their function is required.

Specific requirements for each IROFS will be contained in the ISA.

NFS gave appropriate consideration to the purchase of equipment and instruments by a determination of applicability and specifying proper sizing and materials of construction. Periodic testing, inspection, and maintenance of IROFS will insure availability and operability.

Chemical Protection

The design must provide for adequate protection against chemical risks produced from licensed material, facility conditions which affect the safety of licensed material, and hazardous chemicals produced from license material.

Chemical hazards are evaluated for each process area in Section 3 of this ISA Summary. The significant chemical hazards from both worker and public exposure consequences are identified along with safety controls that will be applied. For those hazards determined to result in high or intermediate exposure levels, as defined in Section 7, IROFS are identified to mitigate or prevent the

postulated accident scenarios. Therefore, chemical protection is addressed in Sections 3, 4 and 6 of the ISA Summary.

Emergency Capability

In accordance with 10 CFR 70.64(a)(6), the design of the BPF will provide for emergency capability to maintain control of:

(i) Licensed material and hazardous chemicals produced from licensed material;

The design bases for the planned measures at the BLEU Preparation Facility (BPF), which will control access to licensed material and hazardous chemicals produced from licensed materials are:

1. NRC Category I security requirements. These requirements are described in NFS security plan, NFS-SEC-C1-PSP.

2. An evacuation system in accordance with applicable sections of ANSI Standard 8.23, Nuclear Criticality Accident Emergency Planning and Response.

3. An Emergency Response Organization (ERO) in accordance with ANSI Standard 8.23, Nuclear Criticality Accident Emergency Planning and Response.

4. A chain of command system similar to the Incident Command System used by FEMA and all major response organizations.

A system established in accordance with ANSI Standard 8.23, Nuclear Criticality Accident Emergency Planning and Response, provides measures to control potential exposure to licensed material and hazardous chemicals at the BPF Complex. The specific item in the standard is "Sufficient exits from the immediate evacuation zone which provide rapid and unobstructed evacuation of personnel." The number of exits in the BPF meets the requirements of the Life Safety Code.

The ERO system as described in Chapter 4 of the Emergency Plan reduces the risk of potential exposure to on-site and off-site emergency responders. The ERO System follows a chain of command structure. The Emergency Control Director (ECD) with the support of Emergency Response Organization members who have the necessary training and expertise directs all emergency response measures, including approval for off-site agency personnel and vehicles (e.g. Fire Department and Ambulance Service) to enter the facility.

(ii) Evacuation of on-site personnel;

The design bases for the items addressed in the NFS Emergency Plan to ensure control of the evacuation of on-site personnel are:

1. A criticality detection system in accordance with requirements of 10 CFR 70.24 and ANSI/ANS Standard 8.3, Criticality Accident Alarm System
2. An evacuation system, in accordance with ANSI Standard 8.23, Nuclear Criticality Accident Emergency Planning and Response including the following elements:
   a. Timely evacuation: When an evacuation is initiated all personnel within the immediate evacuation zone shall evacuate without hesitation by planned evacuation route to an established assembly area.
   b. Equipment and personnel are available for radiological assessment of the assembly location and evacuated personnel.
   c. Sufficient exits from the immediate evacuation zone are provided to enable rapid and unobstructed evacuation of personnel.
   d. Evacuation route and assembly area are clearly posted.
   e. Evacuation route minimizes the total risk considering all potential hazards.
3. A dose level for determination of a safe evacuation assembly area based on ANSI Standard 8.3, Criticality Accident Alarm System, and its definition for an excessive radiation dose as 12 rad.
4. An assembly area accessible by emergency agencies for triage and transport of victims.

(iii) Onsite emergency facilities and services that facilitate the use of available offsite services.

The design bases for the items addressed in the NFS Emergency Plan to ensure control of the onsite emergency facilities and services that facilitate the use of available offsite services is found in applicable sections of ANSI Standard 8.23, Nuclear Criticality Accident Emergency Planning and Response. The elements include the following;

1. An ERO and support teams with appropriate expertise and experience. Regular training and exercises provided to the team members.
2. The emergency facilities, which support the BPF located outside the immediate evacuation zone.

3. Appropriate monitoring equipment, emergency response documents and protective clothing/equipment housed in the emergency facilities.

4. Contents of the emergency facilities inspected on a regular frequency.

5. Letters of agreement for support by off-site agencies.

6. Training and orientation to off-site agencies occurring on an annual basis.

7. An emergency message information system for timely notification to off-site agencies established.

The design basis for the selection of offsite Emergency Facilities is as follows:

1. Timely response:

   a. The performance of the Erwin Fire Department to area fires indicates that they can respond in less than 10 minutes.

   b. Unicoi County Hospital is located five minutes away.

   c. Johnson City Medical Center is located approximately 20 minutes by ambulance and less than 15 minutes by air transport.

2. Sufficient trained personnel:

   a. Our primary Fire Fighting agency is the Erwin Fire Department who routinely sees response of about 15 persons to a fire event. The agency has cooperative agreements with nearby county agencies (volunteer and paid) for further support.

   b. Quality Care Ambulance Service - The agency has two ambulances with available additional resources from neighboring counties and states. Quality Care works with Wings Air Rescue for air transports. The neighboring counties and states would be able to respond in 30 to 45 minutes. The agency has a dispatch system for acquiring sufficient support.

3. Hospital with Level One Trauma Center Capabilities:

   a. Johnson City Medical Center is rated as a Trauma One Center. Oak Ridge's Radiation Emergency Assistance Center Training Site (REAC/TS) has reviewed JCMC capabilities and has stated that they would be an appropriate hospital for victims of nuclear criticality and radiation accidents.

4. Hospitals equipped to handle persons with radioactive contamination:

Both JCMC and the local hospital, Unicoi County Hospital has a program, trained staff and equipment to respond to a radiation accident.

Utility Services

The design must provide continued operation of essential utility services. The new process is designed to be compatible with existing utility services.

Electrical power to the criticality alarm system is the only essential utility to the BPF. The BPF criticality detectors and alarms are supplied emergency power by means of the existing plant emergency power system.

Inspection, Testing, and Maintenance

The design of IROFS must provide for adequate inspection, testing, and maintenance to ensure their availability and reliability to perform their function when needed.

Inspection, testing, and maintenance of IROFS are addressed in Section 4.4 of this report. The level of management measures applied to administrative and engineered IROFS are defined in Tables 6-1 through 6-7. IROFS credited with a high level of risk reduction will be inspected, tested, and maintained on a more frequent and thorough basis than IROFS with lower levels of risk reduction. Also, the design of credited IROFS will include adequate measures for periodic testing, maintenance, and inspection, for verification of safety function performance.

Criticality Control

The design must provide for criticality control including adherence to the double contingency principle.

Criticality safety evaluations are performed for each BPF process to determine the required controls to ensure all processes will be subcritical under normal and credible upset conditions. The criticality safety evaluations document adherence to the double contingency principle, which requires at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible. The required IROFS for protection from credible criticality events are identified in Table 6-1.

Instrumentation and Controls

The design must provide for inclusion of instrumentation and control systems to monitor and control the behavior of IROFS.

The definition for "Instrumentation and Control Systems," is as follows:

> An engineered (PLC internal diagnostic checks, temperature control system logic readouts, etc.) or administrative system (periodic functional

tests, operator surveillance, etc.) that serves to provide timely information on parameters or essential utilities that are used by the IROFS to perform its function.

Periodic Functional Testing:

Engineering analysis and experience will be used to establish functional tests and test frequencies guided by available information about IROFS performance. This information may include reliability, accuracy, and failure rates provided by the supplier. Other consideration such as operating environment, critical parameters, materials of construction, and previous operating experience will be used as applicable in the evaluation. The operating range required of the equipment will impact testing frequency. The smaller the operating range the more frequently an instrument would be tested to mitigate the effects of calibration or instrument drift.

Essential Utilities:

If essential utilities are required for the IROFS to function, those essential utilities fall within the boundaries of the IROFS and have hardwired instrumentation and control systems to monitor the behavior of the IROFS.

NFS monitors two types of IROFS: IROFS that require essential utilities to perform their function and/or IROFS that control a specific parameter as part of their function. NFS performs a formal documented setpoint analysis, functional test and functional test frequency analysis to ensure all engineered IROFS and alarms function when demanded. The functional test frequency is established to provide timely information on critical parameters by ensuring the IROFS functions when demanded. In addition, the functional test simulates the IROFS function critical parameters. The setpoint analysis, functional test and functional testing frequency establish the IROFS critical parameter and adequately monitor the IROFS critical parameter behavior as required by 10 CFR 70.64 (a)(10).

The BPF has no IROFS that require essential utilities to perform their function. Therefore, due to the fail-safe nature, functional testing at an approved test frequency adequately meets the instrumentation and control system requirement specified in 10 CFR 70.64 (a)(10). If essential utilities are required for the IROFS to function, those essential utilities will fall within the boundaries of the IROFS and have hardwired instrumentation and control systems to monitor the behavior of the IROFS.

Defense in Depth

Facility system design and facility layout must be based on defense-in-depth practices.

Defense in depth principles are addressed in BPF operations through the listed IROFS, and supporting programs and analyses (NCSEs and FHAs). The listed IROFS provide successive levels of protection for postulated failures and events. The NCSEs and the FHA provide additional defense-in-depth practices to supplement the designated IROFS and provide an added degree of redundancy for fire and criticality protection controls. The Chemical and Radiological Safety programs for worker and public protection provide similar defense-in-depth protection (Part I and II of License SNM-124). These programs and safety analyses will be implemented as part of the BPF design to ensure that defense-in-depth is adequately addressed including preference for engineered controls over administrative controls and reduction of IROFS challenges.

Table 6-8
Baseline Design Criteria for Active Engineered IROFS

IROFS Active Engineered		Baseline Design Criteria for Engineered IROFS (10 CFR 70.64) Notes: x = Baseline Design Criteria applies to the listed IROFS. a = Fire detection provided in area. Combustible control and manual fire suppression provided in area. b = Materials of construction applied for chemical or environmental protection. c = Design incorporates protective action to provide for continued operation of essential utility services.								
ID	Safety Function	Qual. Std. Eng. Spec. or Dwg.	Seis. Qual.	Other Nat. Phenom.	Env. Prot.	Dyn. Eff.	Chem. Prot.	Ess. Util. Serv.	Inst. & Controls	Def. in Depth
[redacted]	Close on loss of air	x	0	0	0	0	b	c	x	x

Table 6-9
Baseline Design Criteria for Passive Engineered IROFS

IROFS Passive Engineered		Baseline Design Criteria for Engineered IROFS (10 CFR 70.64) Notes: x = Baseline Design Criteria applies to the listed IROFS. a = Fire detection provided in area. Combustible control and manual fire suppression provided in area. b = Materials of construction applied for chemical or environmental protection. c = Design incorporates protective action to provide for continued operation of essential utility services.								
ID	Safety Function	Qual. Std. Eng. Spec. or Dwg.	Seis. Qual.	Other Nat. Phenom.	Env. Prot.	Dyn. Eff.	Chem. Prot.	Ess. Util. Serv.	Inst. & Controls	Def. in Depth
[redacted]	Favorable geometry tank	x	x	a	0	0	b	0	0	x

7.0 CHEMICAL AND RADIOLOGICAL CONSEQUENCE STANDARDS

Section 70.61 of 10 CFR 70 defines the worker, public, and environmental exposure levels for determining High and Intermediate consequence events. The radiological exposure levels are specifically defined in rem, while the chemical exposure levels are qualitatively identified in terms of worker or public health affects. Appendix A, Table A-5, to Chapter 3 of NUREG 1520 provides chemical exposure level guidance in terms of ERPG for each qualitative level in 10 CFR 70.61. This guidance will be used for chemical exposure levels in the BPF analysis.

Table 7-1 below identifies the radiological exposure levels from 10 CFR 70.61, along with the chemical exposure levels from NUREG 1520. Table 7-2 supplements Table 7-1 by specifically defining the 5000 times 10 CFR 20 Appendix B limits. Table 7-3 specifically defines the ERPG-1, ERPG-2, and ERPG-3 levels for each chemical used in the BPF processing operations. Where ERPG levels have not been established, Temporary Emergency Exposure Limits (TEEL) developed by the Department of Energy (DOE) Subcommittee on Consequence Assessment and Protective Actions (SCAPA) have been adopted.

The exposure levels defined by Tables 7-1, 7-2, and 7-3 are used as the basis for determining High, Intermediate, and Low consequence events identified in Section 4.2 of this report.

Table 7-1
10 CFR 70.61 Radiological and Chemical Consequence Exposure Levels

Consequence Level	Radiological		Chemical	
	Worker	Public	Worker	Public
High	TEDE ≥ 100 rem	TEDE ≥ 25 rem	≥ ERPG3	≥ERPG2 ≥30 mg sol. U
Intermediate	TEDE ≥ 25 rem TEDE < 100 rem	TEDE ≥ 5 rem TEDE < 25 rem 5000 x 10 CFR 20, Table 2, App. B limits averaged over 24-hour period	≥ ERPG2 <ERPG3	≥ERPG1 <ERPG2
Low	<Intermediate Levels	<Intermediate Levels	<Intermediate Levels	<Intermediate Levels

Table 7-2
10 CFR 20, Appendix B (Table 2) Concentrations for BPF

Constituent	Solubility Class D		Solubility Class W		Solubility Class Y		Minimum Concentration		5000 x Minimum Concentration	
	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)
U-232	6.E-13	6.E-08	5.E-13		1.E-14		1.E-14	6.E-08	5.E-11	3.E-04
U-233	3.E-12	3.E-07	1.E-12		5.E-14		5.E-14	3.E-07	3.E-10	2.E-03
U-234	3.E-12	3.E-07	1.E-12		5.E-14		5.E-14	3.E-07	3.E-10	2.E-03
U-235	3.E-12	3.E-07	1.E-12		6.E-14		6.E-14	3.E-07	3.E-10	2.E-03
U-236	3.E-12	3.E-07	1.E-12		6.E-14		6.E-14	3.E-07	3.E-10	2.E-03
U-238	3.E-12	3.E-07	1.E-12		6.E-14		6.E-14	3.E-07	3.E-10	2.E-03
Th-228			3.E-14	2.E-07	2.E-14		2.E-14	2.E-07	1.E-10	1.E-03
Th-230			2.E-14	1.E-07	3.E-14		2.E-14	1.E-07	1.E-10	5.E-04
Th-231			9.E-09	5.E-05	9.E-09		9.E-09	5.E-05	5.E-05	3.E-01
Th-232			4.E-15	3.E-08	6.E-15		4.E-15	3.E-08	2.E-11	2.E-04
Th-234			3.E-10	5.E-06	2.E-10		2.E-10	5.E-06	1.E-06	3.E-02
Pu-238			2.E-14	2.E-08	2.E-14		2.E-14	2.E-08	1.E-10	1.E-04
Pu-239/240			2.E-14	2.E-08	2.E-14		2.E-14	2.E-08	1.E-10	1.E-04
Pu-241			8.E-13	1.E-06	1.E-12		8.E-13	1.E-06	4.E-09	5.E-03
Am-241			2.E-14	2.E-08			2.E-14	2.E-08	1.E-10	1.E-04
Np-237			1.E-14	2.E-08			1.E-14	2.E-08	5.E-11	1.E-04
Thorium Series										
Ra-228	2.E-12	6.E-08	2.E-12	6.E-08	2.E-12	6.E-08	2.E-12	6.E-08	1.E-08	3.E-04
Ac-228	2.E-11	3.E-05	8.E-11	3.E-05	6.E-11	3.E-05	2.E-11	3.E-05	1.E-07	2.E-01
Ra-224	2.E-12	2.E-07	2.E-12	2.E-07	2.E-12	2.E-07	2.E-12	2.E-07	1.E-08	1.E-03
Pb-212	5.E-11	2.E-06	5.E-11	2.E-06	5.E-11	2.E-06	5.E-11	2.E-06	3.E-07	1.E-02
Bi-212	3.E-10	7.E-05	4.E-10		4.E-10		3.E-10	7.E-05	2.E-06	4.E-01
Tl-208										
Uranium Series										
Pa-234			1.E-08	3.E-05	9.E-09		9.E-09	3.E-05	5.E-05	2.E-01
Pa-234m										
Ra-226			9.E-13	6.E-08			9.E-13	6.E-08	5.E-09	3.E-04
Actinium Series										
Pa-231			6.E-15	6.E-09	8.E-15		6.E-15	6.E-09	3.E-11	3.E-05
Ac-227	1.E-15	5.E-09	4.E-15		6.E-15		1.E-15	5.E-09	5.E-12	3.E-05
Th-227			5.E-13	2.E-06	5.E-13		5.E-13	2.E-06	3.E-09	1.E-02
Ra-223			9.E-13	1.E-07			9.E-13	1.E-07	5.E-09	5.E-04
Fission Products										
Sr-90	3.E-11	5.E-07			6.E-12		6.E-12	5.E-07	3.E-08	3.E-03
Tc-99	8.E-09	6.E-05	9.E-10				9.E-10	6.E-05	5.E-06	3.E-01
Cs-134	2.E-10	9.E-07					2.E-10	9.E-07	1.E-06	5.E-03

Table 7-2
10 CFR 20, Appendix B (Table 2) Concentrations for BPF

Constituent	Solubility Class D		Solubility Class W		Solubility Class Y		Minimum Concentration		5000 x Minimum Concentration	
	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)	Air (uCi/ml)	Water (uCi/ml)
Cs-137	2.E-10	1.E-06					2.E-10	1.E-06	1.E-06	5.E-03
Pm-147			3.E-10	7.E-05	2.E-10		2.E-10	7.E-05	1.E-06	4.E-01
Eu-154			3.E-11	7.E-06			3.E-11	7.E-06	2.E-07	4.E-02

Table 7-3
Chemical Exposure Standards for BPF

Chemical Name	Symbol	Process UM = Uranium Metal UAl = U Aluminum Dissolution SX = Solvent Extraction DB = Downblending LD = Liquid Discard PV = Process Ventilation	Intermediate Consequence Public ≥ ERPG 1 < ERPG 2 (mg/m³)	High Consequence Public ≥ ERPG 2 (mg/m³)	Intermediate Consequence Worker ≥ ERPG 2 < ERPG 3 (mg/m³)	High Consequence Worker ≥ ERPG 3 (mg/m³)
Ammonia	NH_3	UAl	≥ 17.5 (25 ppm) ≤ 105 (150 ppm)	≥ 105 (150 ppm)	≥ 105 (150 ppm) ≤ 525 (750 ppm)	≥ 525 (750 ppm)
Argon	Ar	UM	≥ 350,000 (210,000 ppm) ≤ 500,000 (350,000 ppm)	≥ 500,000 (350,000 ppm)	≥ 500,000 (350,000 ppm) ≤ 750,000 (500,000 ppm)	≥ 750,000 (500,000 ppm)
Barium Carbonate**	$BaCO_3$	UAl, LD	≥ 0.75 ≤ 6	≥ 6	≥ 6 ≤ 500	≥ 500
Barium Nitrate**	$BaNO_3$	UAl, LD	≥ 2.5 ≤ 4	≥ 4	≥ 4 ≤ 75	≥ 75
Hydrogen	H	UAl, PV	≥ 3,500 (41,000 ppm)	≥ 3,500 (41,000 ppm)	≥ 3,500 (41,000 ppm)	≥ 3,500 (41,000 ppm)
Hydrogen Peroxide, 31%	H_2O_2	UM	≥ 14 (10 ppm) ≤ 71 (50 ppm)	≥ 71 (50 ppm)	≥ 71 (50 ppm) ≤ 142 (100 ppm)	≥ 142 (100 ppm)
Normal Paraffin Hydrocarbon (Norpar-12)	None	SX	≥ 2,000 (300 ppm)	≥ 2,000 (300 ppm)	≥ 2,000 (300 ppm)	≥ 2,000 (300 ppm)
Nitric Acid	HNO_3	UM, UAl, U Nat., SX, PV, DB, LD	≥ 3 (1 ppm) ≤ 15 (6 ppm)	≥ 15 (6 ppm)	≥ 15 (6 ppm) ≤ 200 (78 ppm)	≥ 200 (78 ppm)
Nitrogen	N	UM, UAl, DB, SX	≥ 250,000 (210,000 ppm) ≤ 400,000 (350,000 ppm)	≥ 400,000 (350,000 ppm)	≥ 400,000 (350,000 ppm) ≤ 600,000 (500,000 ppm)	≥ 600,000 (500,000 ppm)
NOX (ERPGs for NO_2)	NO_x	PV, UM, UAl, SX, U Nat	≥ 1.88 (1 ppm) ≤ 27 (15 ppm)	≥ 27 (15 ppm)	≥ 27 (15 ppm) ≤ 56.4 (30 ppm)	≥ 56.4 (30 ppm)

Table 7-3
Chemical Exposure Standards for BPF

Chemical Name	Symbol	Process UM = Uranium Metal UAl = U Aluminum Dissolution SX = Solvent Extraction DB = Downblending LD = Liquid Discard PV = Process Ventilation	Intermediate Consequence Public ≥ ERPG 1 < ERPG 2 (mg/m³)	High Consequence Public ≥ ERPG 2 (mg/m³)	Intermediate Consequence Worker ≥ ERPG 2 < ERPG 3 (mg/m³)	High Consequence Worker ≥ ERPG 3 (mg/m³)
Sodium Aluminate**	NaAl	UAl, SX, LD	≥ 6 ≤ 10	≥ 10	≥ 10 ≤ 50	≥ 50
Sodium Carbonate**	Na_2CO_3	SX	≥ 30 ≤ 50	≥ 50	≥ 50 ≤ 500	≥ 500
Sodium Hydroxide **	NaOH	UAl, PV, LD	≥ 0.5 ≤ 5	≥ 5	≥ 5 ≤ 50	≥ 50
Sodium Nitrate	Na_2NO_3	UAl, LD	≥ 1 ≤ 7.5	≥ 7.5	≥ 7.5 ≤ 100	≥ 100
Sodium Nitrite	Na_2NO_2	UAl, LD	≥ 0.125 ≤ 1	≥ 1	≥ 1 ≤ 7.5	≥ 7.5
Tributyl Phosphate	$(C_4H_9)_3PO_4$	SX	≥ 6 (0.6 ppm) ≤ 10 (1 ppm)	≥ 10 (1 ppm)	≥ 10 (1 ppm) ≤ 300 (30 ppm)	≥ 300 (30 ppm)
Uranium (soluble)*** (includes Uranyl Nitrate, Uranium Trioxide)	U	UM, DB, SX, UAl, LD	N/A	≥ 30 mg	≥ 30 mg ≤ 40 mg	≥ 40 mg

*All chemical exposure levels are based on TEEL values, except Ammonia, Hydrogen Peroxide, Nitric Acid, and Sodium Hydroxide which have established ERPG values. Some chemicals were calculated based on ppm units instead of mg/m³. For these chemicals the ppm value is in parentheses.

** TEEL/ERPG limit listed as solid. Applicability of limits addressed in individual scenarios.

***The worker soluble high consequence Uranium exposure level is based on NUREG/CR-6410 Section 5.8.3.1 and NUREG-1391 which identify 40 mg as the limit for permanent renal damage

NOTE: As per DOE-STD-1136-2000, Page 2-29, for Class Y materials radiological hazards are limiting for enrichments >0.82%. Therefore, the following materials were not evaluated for chemical toxicity: Sodium Diuranate, Uranium Dioxide, Triuranium Octaoxide, Uranium Metal, and U Aluminum alloy.

8.0 SOLE IROFS IN THE BPF

As documented in the Risk Assessment tables in Section 4.3, there are several accident scenarios where only one IROFS is required to meet the performance criteria of 10 CFR 70.61. Table 8-1 specifically identifies the IROFS and accident sequences determined acceptable with one IROFS. There were no High consequence scenarios that relied on a single IROFS for preventing or mitigating postulated accidents. As with all IROFS, appropriate management measures will be applied to these single IROFS as described in Section 4.4 to ensure they are available and reliable to perform their required safety function when needed.

Table 8-1
Sole IROFS for the BPF

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
Active Engineering Controls											
[redacted]		1UALD29.88							Intermediate Hydrogen Explosion	X	
[redacted]		1UALD29.88							Intermediate Hydrogen Explosion	X	

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		2UALD30.88							Intermediate Hydrogen Explosion	X	
[redacted]		2UALD30.88							Intermediate Hydrogen Explosion	X	

Identification	Safety Function Description	What-Ifs							Consequence Level	Mensurement Measures Level	
										A	B
[redacted]		3UALD31:88							Intermediate Hydrogen Explosion	X*	
[redacted]		3UALD31:88							Intermediate Hydrogen Explosion	X*	

Identification	Safety Function Description	What-Ifs							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		4UALD32.88							Intermediate Hydrogen Explosion	X*	
[redacted]		4UALD32.88							Intermediate Hydrogen Explosion	X*	
[redacted]		CMST38.20	CMST38.36	CMST38.47					Intermediate Hydrogen Explosion	X*	

Identification	Safety Function Description	What-If							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		CMST38.20	CMST38.36	CMST38.47					Intermediate Hydrogen Explosion	X	
[redacted]		CMST38.20	CMST38.36	CMST38.47					Intermediate Hydrogen Explosion	X	
[redacted]		CMST38.20	CMST38.36	CMST38.47					Intermediate Hydrogen Explosion	X	
Passive Engineering Controls											
[redacted]		UDB5.78	UDB5.80	UDB5.83	UDB5.84	UDB5.88	UDB5.91	UDB5.93	Intermediate Env Radiological	X	
		UDB5.97	UDB5.100	UDB5.103	UDB5.116	UDB5.129	UDB5.138	UNT7.5			
		UNT7.8	UNT7.12	UNT7.13	UNT7.17	UNT7.19	UNT7.22	UNT7.45			
		1UMD1.147	2UMD2.147	1UMD1.148	2UMD2.148	1UMD1.156	2UMD2.156	3DT3.1			
		3DT3.2	3DT3.3	3D3.11	3DT3.33	7DT4.1	7DT4.2	7DT4.3			
		7DT4.4	7DT4.5	7DT4.6	7DT4.17	7DT4.45	UALAC37.3	UALAC37.38			
		UDB5.14	UDB5.16	UDB5.18	UDB5.20	UDB5.22	UDB5.24	UDB5.26			
		UDB5.28	UDB5.30	UDB5.32	UMM8.12						
[redacted]		CMST38.25	CMST38.26						Intermediate Chemical	X	
[redacted]		CMST38.25	CMST38.26						Intermediate Chemical	X	

Identification	Safety Function Description	What-Ifs							Consequence Level	Measurement Measures Level	
										A	B
[redacted]		UNT7.38A							Intermediate Env/ Radiological		X
[redacted]		UNT7.38B							Intermediate Env/ Radiological		X
[redacted]		UNT7.38B							Intermediate Env/ Radiological		X
[redacted]		UNT7.3	UNT7.53						Intermediate Env/ Radiological	X	
[redacted]		UNT7.37	UNT7.39	UNT7.42	UNT7.45				Intermediate Env/ Radiological		X
[redacted]		CMST38.1	CMST38.30	CMST38.39					Intermediate Chemical		X
[redacted]		CMST38.5	CMST38.6						Intermediate Chemical		X
[redacted]		CMST38.28	CMST38.39	CMST38.51					Intermediate Chemical		X
[redacted]		CD27.21	CD27.26						Intermediate Chemical		X
[redacted]		CD27.1							Intermediate Chemical		X
[redacted]		PS45.134							Intermediate Chemical		X
[redacted]		PV45.132							Intermediate Chemical		X

Identification	Safety Function Description	What-If's							Consequence Level	Measurement Measures Level	
										A	B
Administrative/Enhanced Administrative Controls											
[redacted]		UNT7.38B							Intermediate Env/ Radiological	X*	
[redacted]		UNT7.39							Intermediate Env/ Radiological		X
[redacted]		CMST38.52							Intermediate Chemical		X
		CMST38.52							Intermediate Env. Chem		X
[redacted]		CMST38.52							Intermediate Chemical		X
		CMST38.52							Intermediate Env. Chem		X

*These IROFS also support a High consequence event and therefore are assigned a High management measure level.

9.0 DEFINITIONS OF HIGHLY UNLIKELY, UNLIKELY, AND CREDIBLE[1]

Highly Unlikely – Physically possible or credible, but not expected to occur. A Credible Accident Scenario/Sequence, that based upon a graded combination of IROFS such as Active Engineering Controls (AEC), Passive Engineering Controls (PEC) and Administrative Controls, mitigate or prevent the accident from occurring such that a qualitative Likelihood Category 1 (per Table 5-6), or a quantifiable probability of less than or equal to an index of -4 exists. For nuclear criticality safety purposes, a system shown to provide Double Contingency protection is considered Highly Unlikely, provided that the performance requirements specified in 10 CFR 70.61 are fulfilled.

Unlikely – Not expected to occur during the plant lifetime. A Credible Accident Scenario/Sequence that based upon a graded combination of IROFS such as Active Engineering Controls (AEC), Passive Engineering Controls (PEC) and Administrative Controls mitigate or prevent the accident from occurring such that a qualitative Likelihood Category 1 or 2 (per Table 5-6), or a quantifiable probability of less than or equal to an index of -3 exists.

Credible – An event or accident sequence is considered 'credible' unless it is determined 'Not Credible' by meeting one of the three criteria specified below:

- An event whose frequency of occurrence can conservatively be estimated as 1E-5 events per year or less.
- A process deviation that consists of a sequence of many unlikely human actions or errors for which there is no reason or motive, excluding intent to cause harm. In order to be considered not credible, no such sequence of events can ever actually have happened in any fuel cycle facility.
- Process deviations for which there is a convincing argument, based on physical laws or engineering principles that the deviations are not possible, or extremely unlikely. The validity of the argument must not be dependent on any feature of the design or materials which is controlled by the plant's system of IROFS.

[1] Note: For other ISA definitions see the Definition section.

References

1. *Guidelines for Hazard Evaluation Procedures*, 2nd ed., Center for Chemical Process Safety, AIChE, New York, 1992.

2. 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals*, Occupational Safety and Health Administration, Washington, DC, 1992.

3. *Layer of Protection Analysis – Simplified Risk Assessment*, Center for Chemical Process Safety, AIChE, New York, 2001.

4. 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*, U.S. Nuclear Regulatory Commission, Washington, DC, September 2000.

5. A. D. Swain and H. E. Guttman, *Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications*, NUREG/CR-1278, U.S. Nuclear Regulatory Commission, Washington, DC, August 1983.

6. *Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility (Final Report)*, NUREG-1520, U.S. Nuclear Regulatory Commission, Washington, DC, March 2002.

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8. *Nuclear Fuel Cycle Facility Accident Analysis Handbook*, NUREG/CR-6410, U.S. Nuclear Regulatory Commission, Washington, DC, March 1998.

9. *Fire Hazard Analysis BLEU Uranyl Nitrate Building (UNB)*, September 5, 2002

10. *Fire Hazard Analysis, BLEU Preparation Facility*, Rev. 0, August 21, 2002.