Nuclear Fuel Services, Inc.
P.O. Box 337, MS 123
Erwin, TN 37650

(423) 743-9141

AIRBORNE EXPRESS

21G-03-0305
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ACF-03-0407

November 14, 2003

Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

References:
1) Docket No. 70-143; SNM License 124
2) Letter from B.M. Moore to NRC, Licensing Plan of Action to Support the Blended Low-Enriched Uranium Project at Nuclear Fuel Services, dated October 4, 2001 (21G-01-0180)
3) Letter from NRC to B.M. Moore, Nuclear Fuel Services, Inc., Amendment 31 (TAC No. L31535) to Approve Integrated Safety Analysis Plan and Delete License Conditions S-28 through S-38, dated October 30, 2001
4) Letter from B.M. Moore, Supplemental Environmental Report for Licensing Actions to Support the BLEU Project, dated November 9, 2001 (21G-01-0261)
5) Federal Register, Environmental Assessment and Finding of No Significant Impact of License Amendment for Nuclear Fuel Services, Inc., (Vol. 67, No. 131, pp. 45555-45558), issued July 9, 2002
6) Letter from B.M. Moore, License Amendment Request for the Oxide Conversion Building and Effluent Processing Building at the BLEU Complex, dated October 23, 2003 (21G-03-0277)

Subject: Non-Proprietary Version of Integrated Safety Analysis (ISA) Summary for the BLEU Project Oxide Conversion and Effluent Processing Buildings

Dear Sir:

Nuclear Fuel Services, Inc. (NFS) hereby submits the non-proprietary version of the Integrated Safety Analysis (ISA) Summary for the BLEU Project Oxide Conversion and Effluent Processing Buildings to fulfill the commitment made in Reference 6. This summary contains non-proprietary information and is suitable for public disclosure.

NMSS01

If you or your staff have any questions, require additional information, or wish to discuss this, please contact me, or Mr. Rik Droke, Licensing and Compliance Director at (423) 743-1741. Please reference our unique document identification number (21G-03-0305) in any correspondence concerning this letter.

Sincerely,

NUCLEAR FUEL SERVICES, INC.

B. Marie Moore

B. Marie Moore
Vice President
Safety and Regulatory

lsn

Attachment

cc:
Regional Administrator
U.S. Nuclear Regulatory Commission
Region II
Atlanta Federal Center
61 Forsyth Street, SW
Suite 23T85
Atlanta, GA 30303

Mr. William Gloersen
Project Inspector
U.S. Nuclear Regulatory Commission
Region II
Atlanta Federal Center
61 Forsyth Street, SW
Suite 23T85
Atlanta, GA 30303

Mr. Daniel Rich
Senior Resident Inspector
U.S. Nuclear Regulatory Commission

Attachment

ISA Summary
(Non-Proprietary Version)

21T-03-0978
HEA-13

Integrated Safety Analysis Summary

Blended Low-Enriched Uranium Project

Oxide Conversion and Effluent Processing Buildings

Revision 0

October 2003

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ACRONYMS AND ABBREVIATIONS

AAR	Association of American Railroads
ACFM	actual cubic feet per minute
ACGIH	American Conference of Government Industrial Hygienists
ADU	ammonium diuranate
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
CAAS	Criticality Accident Alarm System
CCS	Central Control Station
CFM	cubic feet per minute
CFR	Code of Federal Regulations
CM	configuration management
CPVC	chlorinated polyvinyl chloride
CSXT	CSX Transportation, Inc.
DIW	deionized water
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DR	damage ratio
EMI	electromagnetic interference
EPB	Effluent Processing Building

ERPG	Emergency Response Planning Guidelines
FHA	Fire Hazards Analysis
FANP	Framatome-ANP
FRP	fiberglass reinforced plastic
fpm	feet per minute
g	gram
gpm	gallons per minute
HEPA	high efficiency particulate air (filter)
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	item(s) relied on for safety
ISA	integrated safety analysis
kg	kilogram
kVA	kilovolt ampere
kW	kilowatt
l	liter
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
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
ModCon	Moderation Control
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
NFIP	National Flood Insurance Program
NFPA	National Fire Protection Association
NFS	Nuclear Fuel Services, Inc.
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
NSA	NuclearSafety Associates
NU	natural uranium
OCB	Oxide Conversion Building
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 (1999)
SNM	special nuclear material
SRP	standard review plan
SRS	Savannah River Site
TEDE	total effective dose equivalent
TEELs	Temporary Emergency Exposure Levels
TNT	Trinitrotoluene
UEL	upper explosive limit
UFG	unfavorable geometry
UFL	upper flammable limit
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

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.

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 fence line.

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 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 x 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 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.

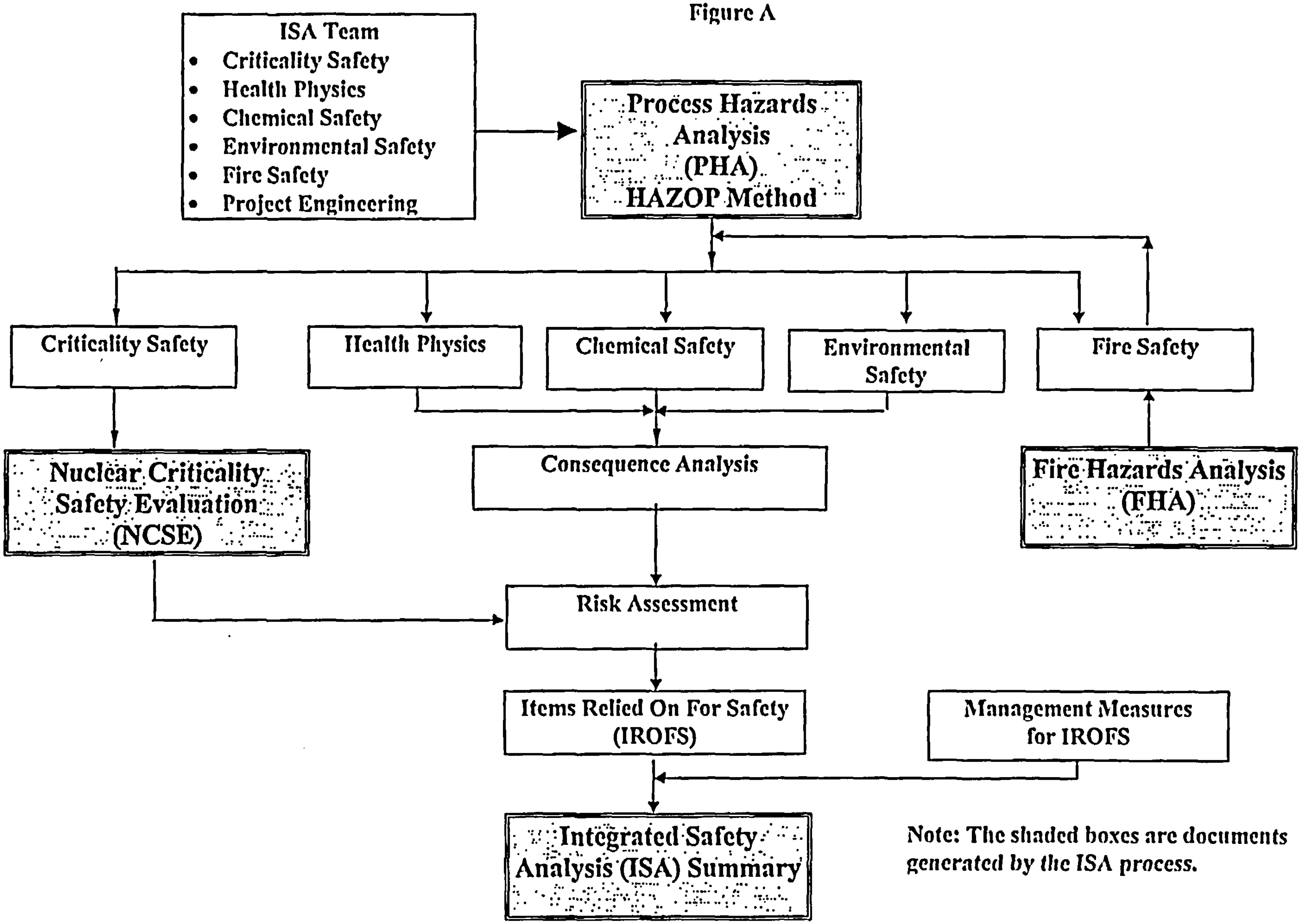
INTRODUCTION AND SUMMARY

This ISA Summary is being submitted by Nuclear Fuel Services, Inc. (NFS) for the Blended Low Enriched Uranium (BLEU) Oxide Conversion Building (OCB) and the Effluent Processing Building (EPB). The OCB and EPB are being constructed within the BLEU Complex area on the NFS Site in Erwin, TN. The OCB and EPB will be licensed under 10 CFR Part 70, enacted on September 29, 2000. The processes within the OCB will convert the low enriched (LE) uranyl nitrate solution into uranium dioxide powder and U_3O_8 powder for off-site shipment. The EPB processes will handle the liquid waste streams from the OCB processes as well as allow for ammonia recovery. According to 10 CFR Part 70, an 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 OCB and EPB designs. This ISA Summary was prepared based on the guidance provided in NUREG-1513 "Integrated Safety Analysis Guidance Document" and NUREG-1520, "Standard Review Plan". Previously, an ISA Summary was submitted for the Uranyl Nitrate Building (UNB) portion of the BLEU Complex. A Safety Evaluation Report (SER) was issued for the UNB by the Nuclear Regulatory Commission on July 8, 2003.

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 A. This process is defined in detail in Section 5 of this ISA Summary.

The information provided in this 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, team qualifications and 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 OCB and EPB 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 items relied on for safety (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.

Figure A



Note: The shaded boxes are documents generated by the ISA process.

1.0 SITE DESCRIPTION

1.1 GEOGRAPHY

The BLEU Complex is located on the NFS Site. 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, 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 NFS 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 BLEU Complex property boundary and the Controlled Area of the site are shown in Figure 1-4. The Controlled Area encompasses the Oxide Conversion Building and the Effluent Processing Building, in addition to the Uranyl Nitrate Building. *The Controlled Area is surrounded by an access control fence line* (property boundary).

The closest BLEU Complex property boundary is approximately 100 feet from the OCB exhaust stack and approximately 80 feet from the OCB. The EPB is approximately 60 feet from the BLEU Complex property boundary and the EPB stack is approximately 90 feet from the property boundary. The closest residence is approximately 450 feet from the site boundary.

1.2 DEMOGRAPHY

The BLEU Complex is located 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 17,667. 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 450 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

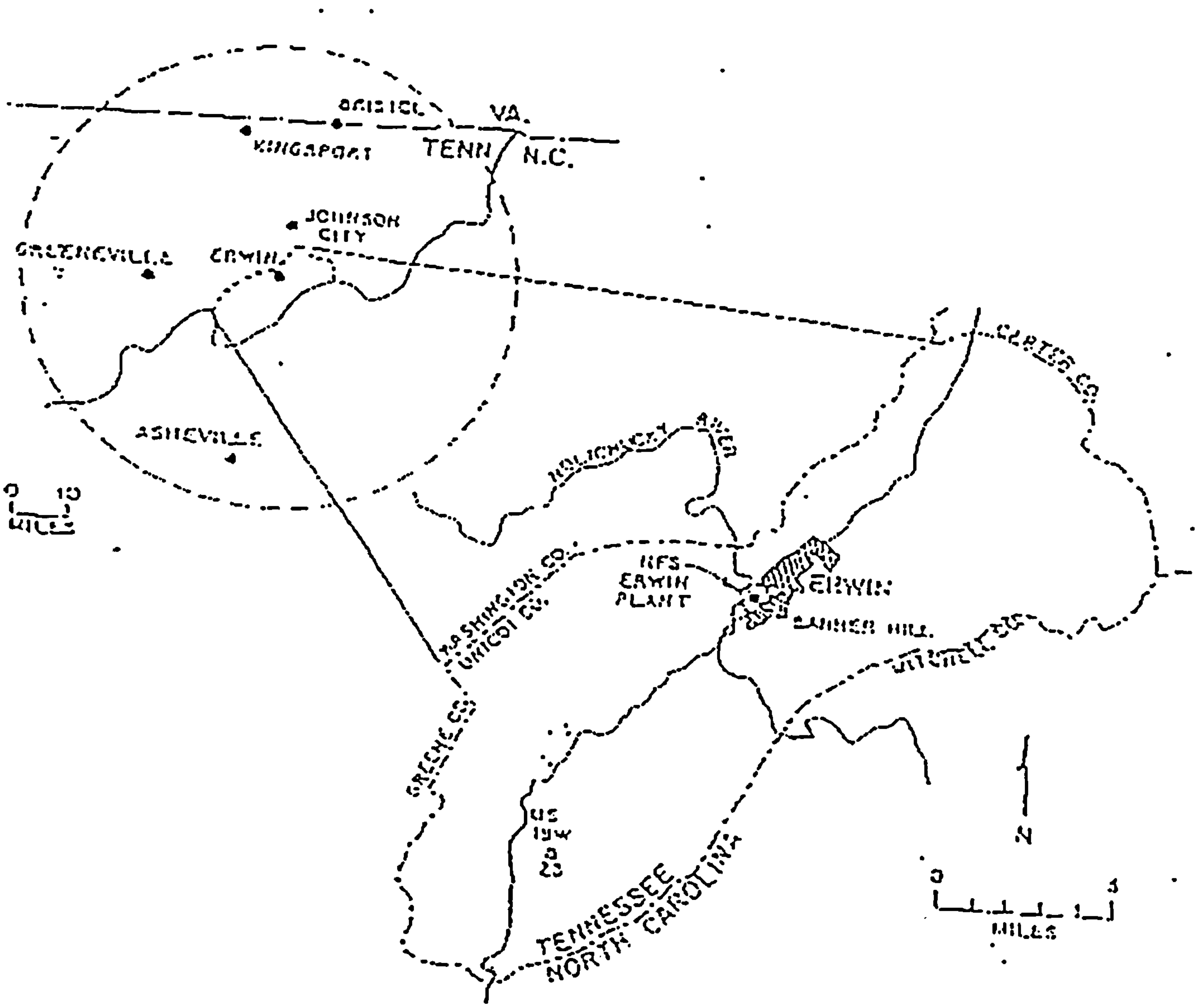


Figure 1-2
Topological Map of NFS Erwin Facility and Surrounding Area

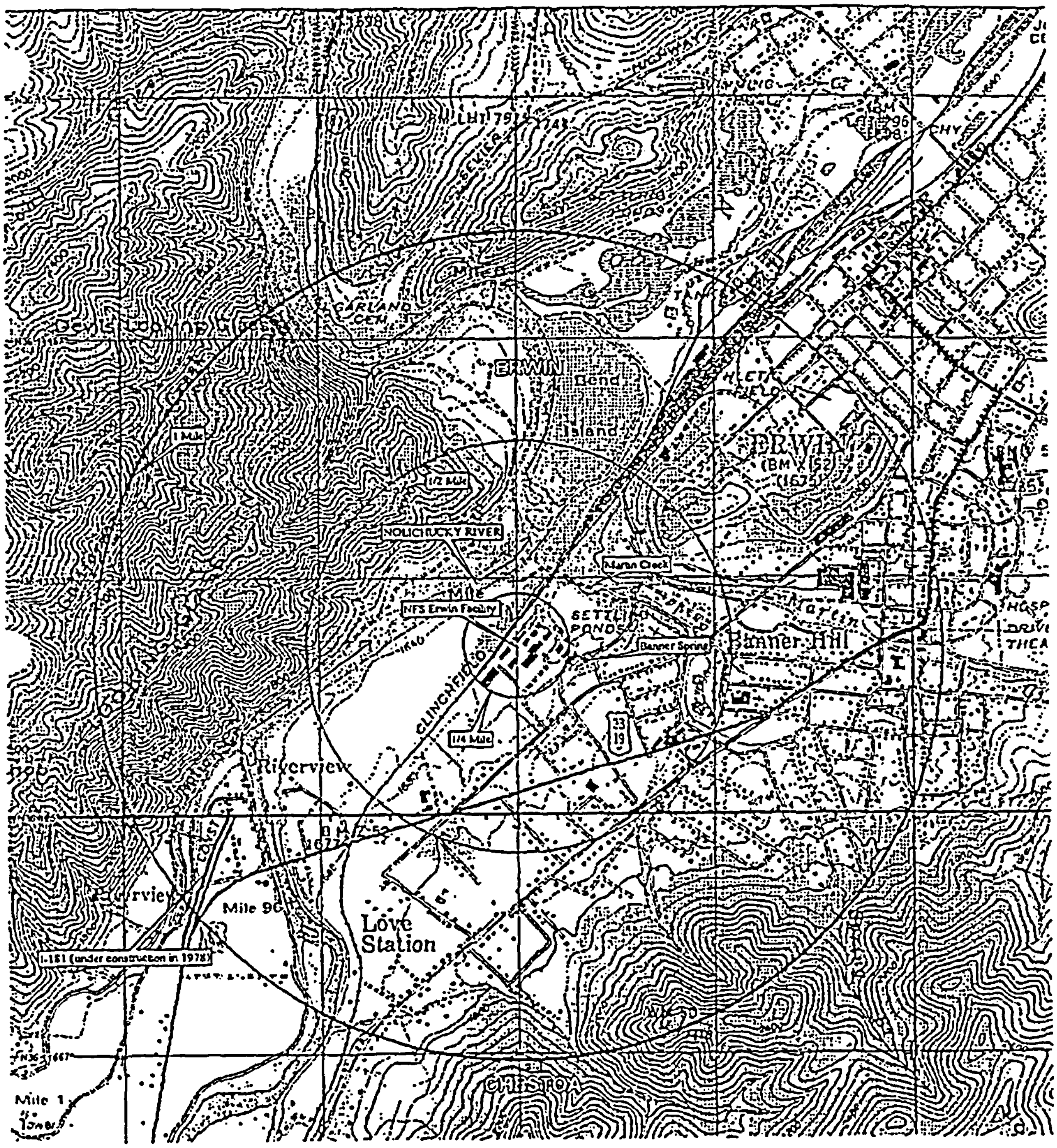


Figure 1-3
NFS Site Area Map

Figure 1-4
BLEU Complex Site Layout

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 licensed low level radioactive waste processing facility located greater than 223 feet southwest of the BLEU Complex. 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 N^{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 by NFS, which may include the activation of its Emergency Response Organization, would be initiated in accordance with the NFS Emergency Plan (Chapter 8 of License SNM-124).

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 OCB/EPB.

Studsvik uses bulk sodium hydroxide inside the process facility building. There are 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 southeast side of their process facility. Below are the tank sources, capacities, pressures and locations relative to the Studsvik process facility.

Liq. Nitrogen	[redacted]al @ 250 psi (Outside and West)
Liq. Oxygen	[redacted]al @ 250 psi (Outside and West)
Sodium Hydroxide	[redacted]al. @ Atm. (Inside process building)
Diesel Fuel	[redacted]al. @ 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 railroad tracks are approximately 220 feet from the OCB and EPB.

The bounding fire from a radiant heat exposure to the OCB or EPB would be an 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 to the OCB or EPB from a property damage standpoint.

LPG rail cars 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 DOT 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 rail car inventory is [redacted]allons (approx. 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.

Based on an LPG tank car being parked in the CSXT rail yard, with no loading or unloading operations, and based on the very strict tank car designs with no BLEVEs or vapor cloud explosions occurring over the last 21 years, the likelihood of having an LPG tank car BLEVE or explosion exposing the OCB or EPB is not considered a significant concern for BLEU Complex operations.

1.2.1.3. Local and Regional Airports

The Tri-Cities Regional Airport is located approximately 40 miles north of the NFS site near the town of Gray, and 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 the NFS. Site. The flight patterns to these airports are not a concern for the BLEU Complex operations.

1.2.1.4. Carolina Avenue

Carolina Avenue runs parallel to the east property boundary of the BLEU Complex. There is only one access point to the BLEU Complex from Carolina Avenue. The vehicle traffic on Carolina Avenue has not been specifically evaluated; however, the road is approximately 500 feet from the BLEU Complex site Controlled Area. Considering this distance, and the controlled area security fencing, vehicles on Carolina Avenue would not be a significant concern for BLEU Complex 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 (NFS Environmental Report, Dec. 1996).

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 Plant meteorological monitoring system. A meteorological monitoring system (wind speed, wind direction and differential temperature) is located just east of Building 305 in the NFS Plant. 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 220 in the NFS Plant. 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 Environmental Report, Dec. 1996).

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

	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 DEGREE 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 ≤ 1/4 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	27	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													

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Table 1-2
Wind Speed/Direction Frequency Data

WIND SPEED/DIRECTION FREQUENCY DATA

Data Collected at the NFS Meteorological Tower, Erwin, Tennessee

Year		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
1991	Frequency (%)	8.0	4.6	3.6	2.4	1.7	1.8	2.8	6.1	10.3	16.6	17.4	6.4	2.6	2.6	3.6	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	1.6	3.8	6.9	12.3	19.0	10.4	4.6	2.1	2.4	6.6	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	3.6	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	6.6	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	3.6
1994	Frequency (%)	6.7	3.9	2.9	2.1	1.7	1.9	2.9	6.3	10.3	19.4	13.6	6.9	2.7	2.2	4.6	12.8
	Avg. Speed (mph)	5.9	4.9	4.3	3.6	3.4	3.6	6.6	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	4.6	3.0	2.4	1.7	1.9	3.9	6.9	12.0	17.6	10.8	6.1	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	6.6	2.6	2.6	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 typical area for tornado activity, south of most blizzard conditions, and too far inland to be affected by hurricane wind conditions. NOAA regional data recorded a maximum sustained wind of 50 mph in the regional area occurred in 1951, and a peak wind gust of 86 mph was reported in 1995. Wind data from the NFS Plant collected over approximately the past three years indicate a maximum sustained wind of 29 mph.

The OCB and EPB are designed to withstand design basis winds per the 1999 Standard Building Code. Heavy rain damage to the OCB and EPB roofs are bounded by snow loading, against which the building is designed per the SBC. Therefore, wind and storms are not of significant concern to BLEU Complex operations.

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 Plant Controlled Area is 0.047 square miles, the average probability is 3.0 E-7 per year for a direct hit at the NFS Plant Controlled Area. This probability is considered conservative since the NFS Plant 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 the east 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 Plant 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 Plant Controlled Area, a damaging tornado is not considered a significant concern for site operations. The BLEU Complex is much smaller than the NFS Plant Controlled Area, so the tornado probability is even lower. In the unlikely event that a tornado did occur, protective actions would be implemented in accordance with the NFS Emergency Plan.

1.3.4 Lightning

A risk analysis for the NFS Site indicates a moderate to severe risk of facilities being damaged by lightning. The BLEU Complex building designs were reviewed for lightning risk and the appropriate protection specified. The OCB and EPB building designs include lightning protection per the applicable building codes (specifically NFPA 780). Therefore, lightning strikes would not be a significant concern for the BLEU Complex.

1.4 HYDROLOGY

The Process Hazards Analysis found no credible accident scenario resulting from local area flooding because the BLEU Complex is well above the 100-year flood plain Base Flood Elevation. As shown in Figure 1-5, only the northern portion of the NFS site is within the 100-year flood plain of Martin Creek. The Town of Erwin participates in the National Flood Insurance Program (NFIP) created by Congress in 1968. Communities that participate in NFIP adopt and enforce flood plain management ordinances that provide flood loss reduction building standards for new and existing development. The lowest floor elevation for buildings that are located in the 100-year flood plain must be at least one foot above the Base Flood Elevation. The OCB or EPB are not located in the 100-year flood plain, and the lowest floor elevation is fifteen feet above the Base Flood Elevation, thus a large margin of safety exists. Therefore, a 100-year flood would not have significant consequences for BLEU Complex operations.

1.5 GEOLOGY AND SEISMOLOGY

1.5.1 Geology

The BLEU Complex 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 the NFS Site 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

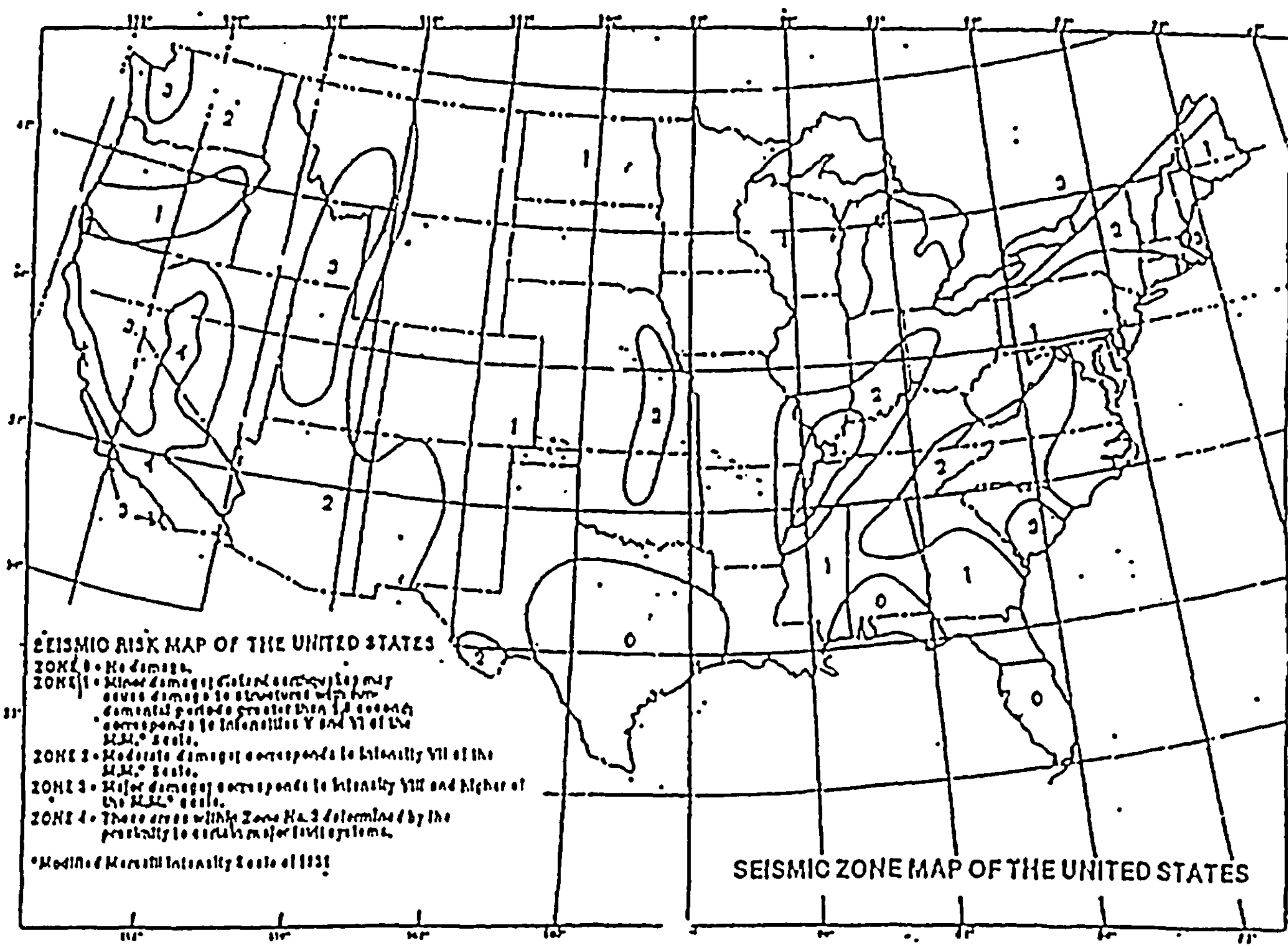
The BLEU Complex, which is on the NFS Site, is located within the Southern Appalachian Tectonic Province, which extends from central Virginia to central Alabama and from the western edge of the Piedmont Province to the Cumberland Plateau Province. The Southern Tectonic Province has a moderate level of historical and recent earthquake activity. The NFS Site location is designated as Seismic Zone IIC in the 1999 Standard Building Code (SBC) 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 the NFS Site.

A seismic analysis of the NFS Site determined there is no evidence of geologically recent fault displacements on the site that would be associated with capable faults in the surrounding region. For a 1000-year return period, the analysis yielded an effective peak horizontal ground acceleration rate of 0.06 gravity.

The OCB and EPB are designed and constructed in accordance with the Standard Building Code (1999).

Figure 1-5
Approximate 100 Year Flood Plain

Figure 1-6
Seismic Zone Map of the United States



2.0 FACILITY DESCRIPTION

2.1 SITE FACILITIES

The BLEU Complex is located on approximately five acres of the NFS Site adjacent to the NFS' Plant. The property lies approximately 800 to 1000 feet from the southeastern bank of the Nolichucky River, and is bounded by Carolina Avenue to the east, the CSXT rail yard to the west, NFS Plant to the north and the Studsvik Processing Area to the south. (See Figure 1-3).

The BLEU Complex will be fenced and will have a 24-hour guard station at the entrance. Site layout concerns that are related to the processing of nuclear materials and worker safety are specifically addressed by the Nuclear Criticality Safety Program, Radiation Protection Program and Fundamental Nuclear Material Control Plan. On-site traffic patterns do not appreciably increase the accident likelihood for either the OCB or EPB. Evacuation routes and emergency vehicle access to the site are planned such that egress during an accident does not increase the risk to employee health nor impede site access for emergency personnel.

The BLEU Complex is comprised of four buildings. Three of the buildings contain the major components and support systems to convert LE UN solution into uranium oxide powder. The UNB provides for the receipt and storage of the UN solution. The ISA Summary for this building was covered under a previous submittal. The OCB contains the equipment to receive the UN from UNB, precipitate uranium from the solution as ammonium diuranate, separate the precipitate slurry into liquid and solid streams, lower the moisture content of the ammonium diuranate through a dryer, reduce the ammonium diuranate to uranium dioxide (UO_2) in a calciner, oxidize some of the UO_2 to U_3O_8, blend batches of powder for homogeneity, off-load the blended powder into shipping packages, and recover uranium from the process liquid stream. The EPB contains equipment to process OCB liquid waste streams by recovering ammonia and concentrating the resulting waste salt solution before treating the salt solution to solidify it and disposing of the purified overheads to the Erwin POTW. A covered truck loading area is also provided outside the EPB for loading shipments of product and solidified waste.

The BLEU Complex site plan is shown in Figure 1-4. The OCB and EPB are separated from the UNB by the approximate distances shown.

2.2 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. During emergencies, off-site agencies requiring access to the BLEU Complex Controlled 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 the NFS Site. 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 a 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 the NFS Site. NFS provides training in contamination control and monitoring to fire department personnel. Fire fighting personnel are trained to know the location of the Moderation Control Area in the OCB.

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.

2.3 OCB DESCRIPTION

The layout for the OCB is shown in Figures 2-1 and 2-2. The OCB processes are designed to take the LE UN solution through a precipitation process in which the uranium in the feed solution is precipitated as ammonium diuranate (ADU) by mixing the UN with ammonium hydroxide. The ADU is fed to a centrifuge to separate solids and liquids. The uranium solids are then sent to a dryer and calciner to produce uranium oxide powder. The uranium oxide powder is blended in batches in a conical blender. Oxide powder is loaded into pails below the blender, which are in turn loaded into shipping packages. Within the OCB, there are process systems to support recovery of soluble and insoluble uranium in the liquid effluent after centrifuge separation, and there are uranium dissolver processes for natural uranium and scrap UO_2 material.

The OCB is a two-story building with approximately 13,150 sq. ft. of floor area. Approximately, 7,860 sq. ft. of this floor area is located on the first floor. The first floor slab is at elevation 1,656 ft. to 1,656.25 ft. with the second floor slab at 1,668.33 ft. The roof levels vary from 12.75 ft. to 40.08 ft. above the 1,656.25 ft. floor elevation. The building is designed as Type IV construction per the Standard Building Code. The exterior walls are designed to meet noncombustible construction requirements.

Figure 2-1
OCB Equipment Layout (First Floor)

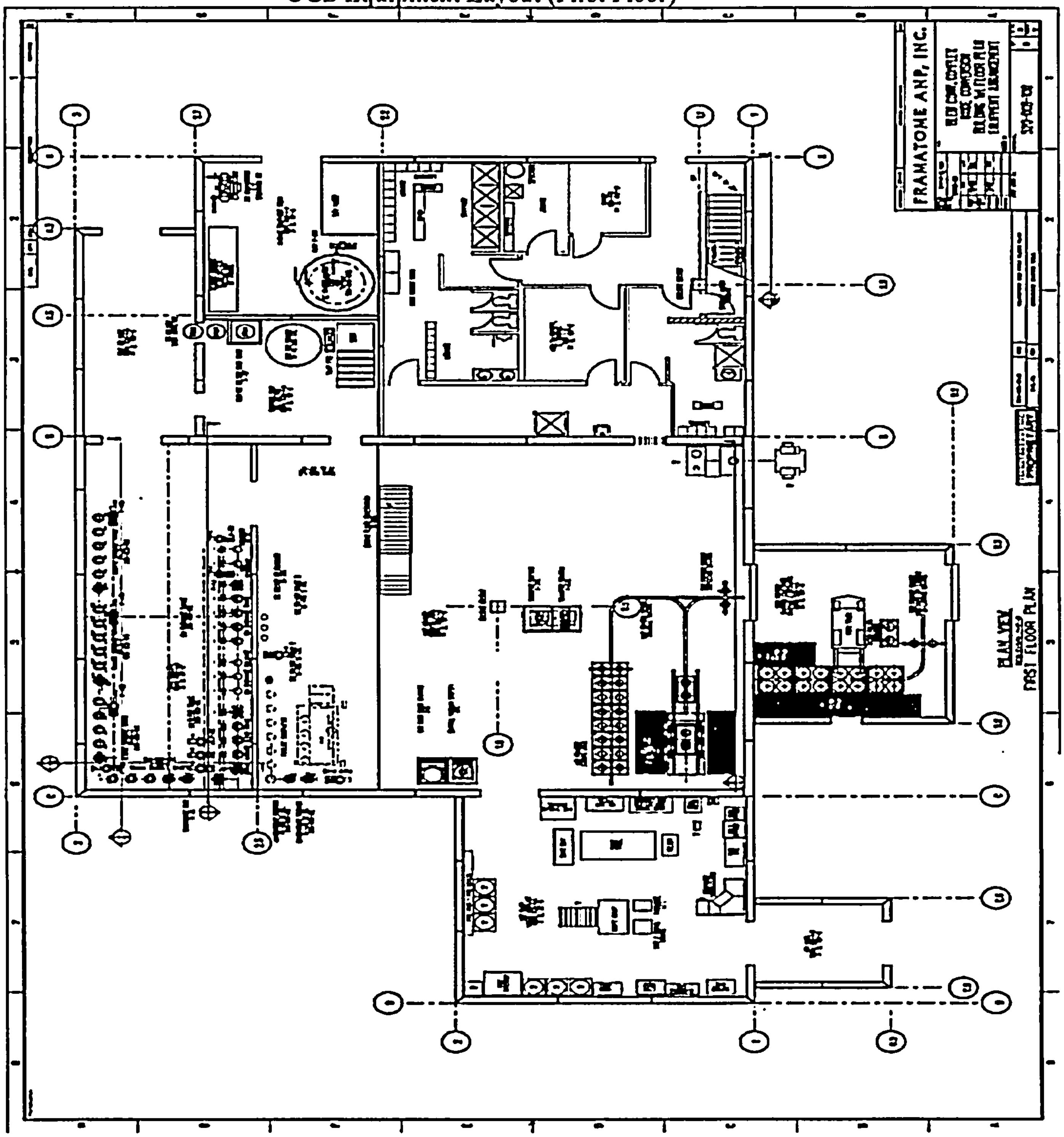
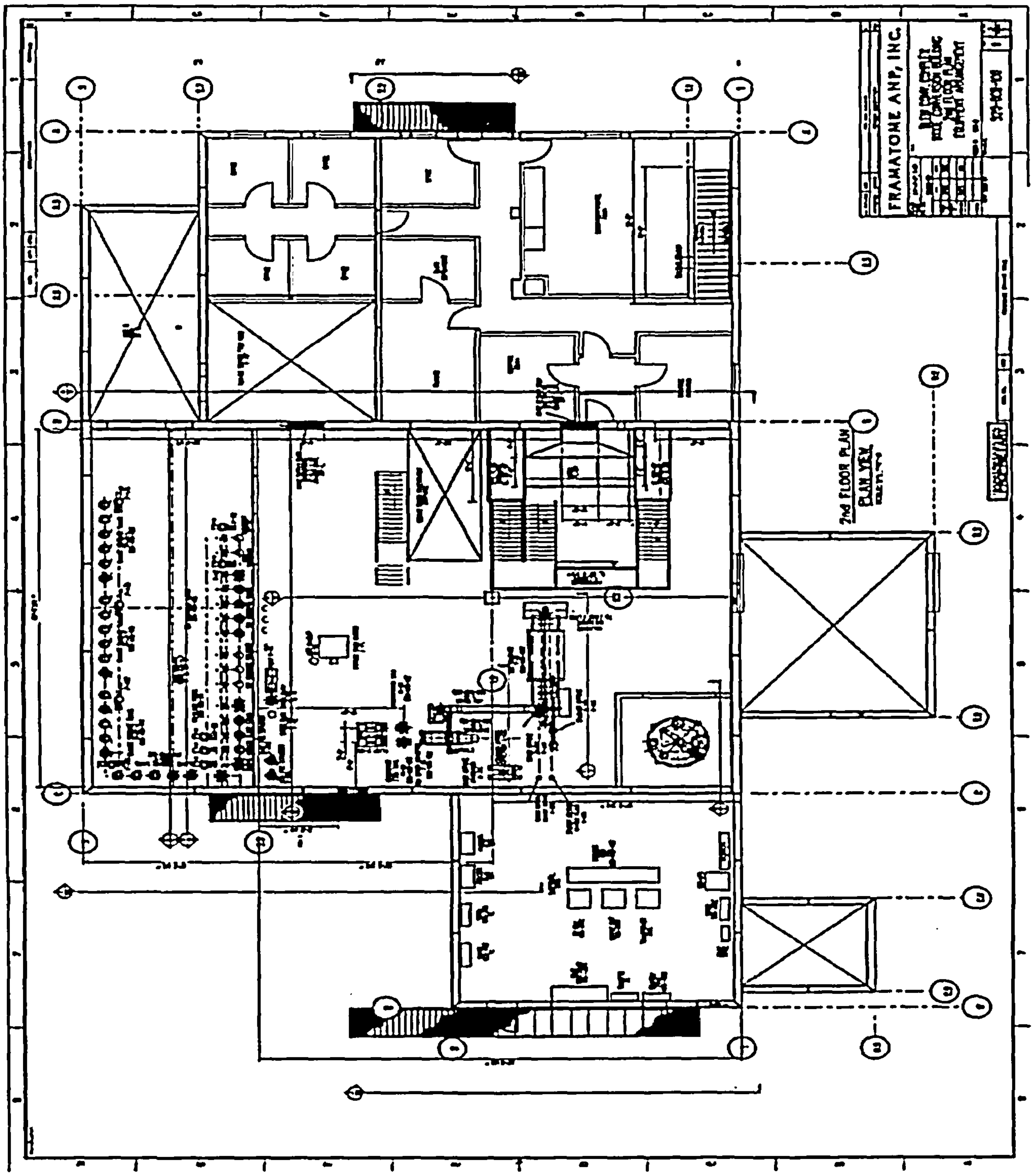


Figure 2-2
OCB Equipment Layout (Second Floor)

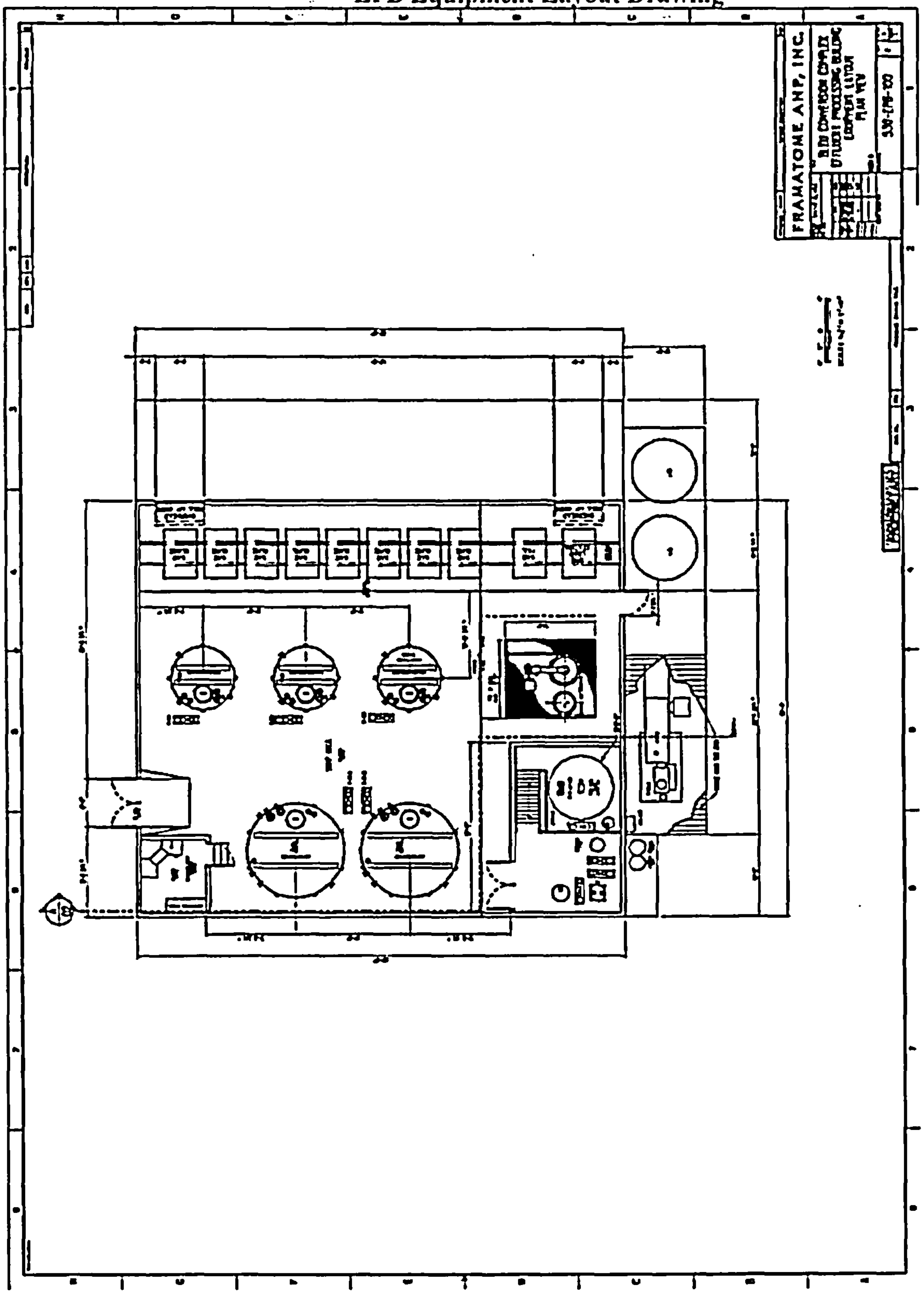


2.4 EPB DESCRIPTION

The layout for the EPB is shown in Figure 2-3. The three major unit operations housed in the EPB are ammonia recovery from the liquid effluent stream, waste solution evaporation, and concentrated waste solidification. Outside the EPB is a steam boiler to provide steam to the ammonia recovery stripper column and evaporator. Also outside of the EPB are storage silos for stabilization solids (clay and cement). These solids are vacuum transferred and mixed with the liquid waste from the evaporator bottoms tanks. The resultant mixture is cured and disposed as a solid low-level radioactive waste. The evaporator overheads are collected in 10,000-gallon tanks for sampling and isolation before discharging to the Erwin POTW system.

The EPB is a one-story building with approximately 2,240 sq. ft. of floor area. There is also approximately 180 sq. ft. of additional floor area under a canopy on the north side. The Electrical Gear Area and Operating Station Area is raised approximately 2 feet above the process area floor elevation. The roof levels vary from 20 ft. to 40 ft. above the process area floor elevation. The building is Type IV construction per the Standard Building Code. The structure is a rigid metal frame covered with metal siding.

Figure 2-3
EPB Equipment Layout Drawing



2.5 UTILITY SYSTEMS

The BLEU Complex site utility and auxiliary systems are described below.

Electrical

The BLEU Complex electrical system consists of a transformer rack, 480 volt AC (VAC) switchgear and motor control centers, 208 VAC and 120 VAC lighting panels. Backup power is provided from the existing diesel generator located by the UNB and automatic transfer switches. Uninterruptible power supplies are provided for key systems where even a short power outage is undesirable.

Compressed Air (CA)

CA for air-operated valves, instruments, and other process uses is supplied by an air compressor located in the OCB Facility Mechanical Room. The CA is filtered and dried before being routed to the compressed air headers in the OCB and EPB

Process/Domestic Water

Water is supplied from the municipal water supply system. A backflow-preventer is installed to prevent accidental contamination of the municipal water system by facility process water.

Deionized Water

A portion of the process water supply is routed to a reverse osmosis package unit which is located in the OCB Facility Mechanical Room. Deionized water (DIW) from the reverse osmosis unit is stored in DIW Storage Tank, TK-DIW. The DIW system includes a tank and pump for reverse osmosis unit pre-treatment chemical injection. Reject water from the reverse osmosis treatment unit is routed into the sanitary waste system that flows to the Erwin POTW system.

DIW is pumped from TK-DIW to facility processes through a supply header. Pump minimum flow is maintained through a restriction orifice that recirculates pump discharge flow back to TK-DIW. System instrumentation includes a reverse osmosis unit discharge water purity monitor, tank level indication, tank low level alarm and DIW supply header pressure monitor.

Process Steam

Process steam for the liquid waste evaporation and ammonia recovery processes is supplied by a natural gas-fired boiler, E-69, located outside the EPB. Steam is supplied to Ammonia Recovery Stripper Column, V-52, and Liquid Waste Evaporator, V-62. Boiler feedwater makeup is supplied by the DIW system.

Bulk Chemical Storage

The bulk chemical storage system provides for onsite storage of process chemicals. This includes bulk storage for liquid hydrogen and liquid nitrogen, as well as vaporizers to provide nitrogen and hydrogen to the process. Bulk storage tanks are also provided for concentrated and dilute nitric acid, sodium hydroxide solution and ammonium hydroxide solution.

Bulk Hydrogen Storage and Vaporization

The bulk hydrogen storage and vaporization system is a package supply system that is owned and maintained by the vendor. The system utilizes a [redacted] gallon horizontal liquid hydrogen tank for storage and a manifold type vaporizer to provide hydrogen gas pressure to the system. The tank is located remotely from the OCB for safety reasons and is protected by a security fence. The system will be routinely monitored by plant personnel for level and other key parameters. Operational, maintenance and safety issues for the system are provided by the vendor.

Bulk Nitrogen Storage and Vaporization

The bulk nitrogen storage and vaporization system is a package supply system that is owned and maintained by the vendor. The system utilizes a [redacted] gallon vertical liquid nitrogen tank for storage and a manifold type vaporizer to provide nitrogen gas pressure to the system. The tank is located next to the OCB. The system will be routinely monitored by plant personnel for level and other key parameters. Operational, maintenance and safety issues for the system are provided by the vendor.

Concentrated and Dilute Nitric Acid Storage Tanks, TK-CNA and TK-DNA

Concentrated (60%) nitric acid is received by truck and stored outside the OCB in tank TK-CNA. TK-CNA is a [redacted] gallon tank equipped with level indication. A pump supplies acid to the process via the concentrated acid header and supplies acid, as required, to the Dilute Nitric Acid Storage Tank, TK-DNA. Minimum flow is provided through a recirculation line and restriction orifice back to TK-CNA to prevent dead-heading the pump.

Deionized water is added to TK-DNA to dilute nitric acid strength to approximately 10% concentration for use in other process systems. TK-DNA is a 5,000-gallon tank equipped with level indicator. A pump supplies acid to the dilute acid header. Minimum flow is provided through a recirculation line and restriction orifice back to TK-DNA to prevent dead-heading the pump.

Sodium Hydroxide Solution Storage Tank, TK-SH

Sodium hydroxide solution (50%) is received by truck and stored outside the OCB in tank TK-SH. TK-SH is a [redacted] gallon tank equipped with a level indicator. Caustic solution is pumped to the caustic solution header. Minimum flow is provided through a recirculation line and restriction orifice back to the tank to prevent dead-heading the pump. Tank temperature is controlled and tank outlet piping is heat-traced to maintain flowability of the sodium hydroxide solution.

Ammonium Hydroxide Solution Storage Tank, TK-AH

Ammonium Hydroxide solution (47%) is received by truck and stored outside the OCB in tank TK-AH. TK-AH is a [redacted] gallon tank equipped with a level indicator. Ammonium hydroxide is pumped to the ammonium hydroxide header. Minimum flow is provided through a recirculation line and restriction orifice back to tank TK-AH to prevent dead-heading the pump. Ammonium hydroxide recycle from the Ammonia Recovery Process is returned to tank TK-AH. The tank is vented to the ammonia recovery scrubber.

2.6 LIGHTNING PROTECTION SYSTEM

NFS performed a lightning risk analysis for some of its facilities 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). The OCB and EPB are provided with lightning protection in accordance with NFPA 780.

2.7 VENTILATION SYSTEMS

The OCB ventilation systems can be functionally separated into three categories: main process heating, ventilation, and air conditioning (HVAC) system, process exhaust ventilation system and office HVAC system. The recirculating main process HVAC system is designed and operated during processing to maintain a clean and conditioned air supply to the process area of the OCB. The HVAC system (~30,000 cfm) uses HEPA filters to reduce and control contamination throughout the OCB. The process exhaust (~7000 cfm) is HEPA filtered and released from a stack near the OCB. The HVAC office system is designed to provide a conditioned air supply to the OCB office area.

The EPB ventilation system consists of supply fans, exhaust louvers, and electrical heaters. The system is designed to keep the building above 65 degrees Fahrenheit and provide sufficient air circulation to remove excess heat. The small process exhaust (~200 cfm) is sent through HEPA filters to control release of contamination from the EPB stack.

2.8 RADIATION MONITORING

The radiological air sampling system will meet the requirements of License SNM-124. The system will have a vacuum header and air sampling heads in locations identified by Health Physics and Engineering.

2.9 FIRE PROTECTION

2.9.1 Fire Protection Program

The fire protection program for the OCB and EPB was determined through a Fire Hazards Analysis (FHA) based on National Fire Protection Association

Standards, Standard Fire Prevention Code, and Industry Practices. The FHA documents how the fire protection program satisfies the main objectives associated with fire prevention, fire detection and alarm, life safety, fire suppression, and fire response.

2.9.1.1. 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.

<u>Building and Equipment Design - Oxide Conversion Building</u>

The building is designed as Type IV construction per the Standard Building Code. Exterior walls meet noncombustible construction requirements. The exterior walls are approximately 10-12 inches thick consisting of insulated load bearing precast and prestressed concrete panels. The roof consists of precast concrete tee panels covered with 2-inches of flat polyisocyanurate board insulation, 1-inch of purlite insulation, and a coal tar bitumen roofing system. The built-up roof has a Class A rating per Underwriters Laboratories classification.

For criticality safety, the OCB has a designated Moderation Control Area where moderating materials such as water and plastic are strictly limited. Combustible load is also minimized throughout the facility. The Moderation Control Area is not covered by a fire sprinkler. The building includes a double roof design above the Moderation Control Area to prevent rainwater ingress.

Tanks, scrubbers, condensers, process equipment, electrical conduit, ventilation and exhaust ducting within the OCB are constructed of noncombustible materials. Ventilation piping in the non-sprinkled areas is constructed of noncombustible materials with exception of a minor quantity of polypropylene piping (less than 30 pounds). Other combustibles in the non-sprinkled areas consist of LEXAN™ panels and rubber boots for four hoods (Dissolver Powder Hood – less than 65 pounds LEXAN™ and 10 pounds rubber, Calciner Drop Hood – less than 150 pounds LEXAN™ and 10 pounds rubber, Powder Loading Hood – less than 150 pounds LEXAN™ and 10 pounds rubber, and Addback Powder Hood – less than 65 pounds LEXAN™ and 10 pounds rubber). These combustible materials are representative of the materials in the area but are not intended to be combustible material limits. There will also be some minor amounts of combustibles such as wiring insulation and computers in the facility.

Combustible loading in sprinkled areas consist of a hood constructed of less than 200 pounds of LEXAN™ panels and 10 pounds of rubber boots located in the Natural Uranium Dissolver Area, approximately 103 pounds of 1-inch and 1½-inch diameter polypropylene piping located in the tank gallery, and less than 240 pounds of miscellaneous combustible materials located in the Waste Handling Area. These combustible materials are representative of materials in the area and are not intended to be material limits. The Waste Handling Area may contain up to six 55-gallon waste drums filled with rags, paper, and other material. These drums will be closed top when not in use.

Building and Equipment Design - Effluent Process Building

The building is a Type IV-Unprotected construction per the Standard Building Code. The structure consists of a rigid metal frame covered with metal siding. A natural gas fired boiler (less than 7,000 BTU) is located under a metal canopy on the north side of the building. The boiler burner management system is listed by a nationally recognized testing agency.

The ammonia stripper column, the [redacted]allon ammonia recovery receipt tank, and the [redacted]allon liquid waste feed tank are constructed of stainless steel. The ammonium scrubber is constructed of high-density polyethylene. Two 10,000-gallon evaporator overhead Storage tanks and two 5,000-gallon evaporator bottoms storage tanks are constructed of composite fiberglass-reinforced plastic in accordance with ASTM D3299 "Specification for Filament Wound Glass Fiber Reinforced Thermoset Resin Corrosion Resistant Tanks."

The [redacted]allon fiberglass reinforced plastic tanks are constructed to meet a flame spread rating of less than 30 based on ASTM E84 test criteria.

Electrical Systems

All electrical equipment and installation methods will comply with NFPA 70, *National Electrical Code.* Electrical equipment installed within 3 feet of the Conversion Area ceiling, over the envelope of the process equipment which handles hydrogen, will meet the requirements of Class I, Division 2, Group B per the *National Electrical Code.* Electrical equipment within the Ammonia Recovery Area of the EPB will meet the requirements of Class I, Division 2, Group D per the *National Electrical Code.*

With exception of the heaters for the ammonium diuranate dryer and the calciner, electric heaters used in the processes are low watt band and mineral insulated cable heaters and failure of the heaters will not damage the process equipment (heater would burn out).

Ventilation Systems

Ventilation Systems - Oxide Conversion Building

Ventilation systems for the OCB consist of the process off-gas scrubber systems which will discharge to the building process ventilation system, and two recirculating air HVAC units.

Process Ventilation

The base and acid process off-gas scrubber systems, the calciner drop hood, the powder loadout hood, the dissolver loading hood, the natural uranium dissolver hood, the addback powder hood, and the grinder and welder are ventilated through the building process ventilation system.

The building process exhaust ventilation system is designed to provide 6900 CFM of exhaust to an exterior stack and to maintain building negative pressure. Ventilation is exhausted to a metal stack that is approximately 50 feet high. Redundant ventilation fans are provided to ensure the reliability of the ventilation system. These ventilation fans are connected to the emergency power supply for the BLEU Complex. The bulk of ventilation is exhausted through a HEPA filter unit (HF-2) located on the first floor in the southeast portion of the Conversion Area with exception of the acid process off-gas scrubber which is exhausted through a pre-filter and HEPA filter unit (HF-3) located in the second floor Conversion Area. The HF-2 HEPA filter unit has approximately 47.5 sq. ft. of filter surface area and the HF-3 HEPA filter unit has approximately 5 sq. ft. of filter surface area. The pre-filters and HEPA filters meet the criteria of UL 900, Class 1.

Smoke detectors are located in the building process ventilation system downstream of the HF-2 and HF-3 HEPA filter units but upstream of the ventilation fans. The smoke detectors are connected to the fire alarm panel to provide fire alarm notification.

Process Off-Gas System

The calciner and ammonium diuranate dryer are ventilated through the base process off-gas system. The base process off-gas system is designed to maintain a negative pressure on the calciner, calciner filters, and the base process off-gas condenser and scrubber to prevent a release from the equipment including hydrogen. A pressure transmitter and interlock are provided at the calciner to close the hydrogen flow control valve upon detecting loss of negative pressure in the calciner. To minimize the possibility of air entering the base process off-gas system, the ammonium diuranate dryer is purged with nitrogen. Nitrogen is also used for blowback of filters vented to the base process off-gas scrubber system. Tanks and vessels connected to the base process off-gas scrubber are purged with nitrogen to prevent air from entering the base process off-gas scrubber and to prevent hydrogen from being drawn from the base process off-gas scrubber into the tanks and vessels.

Prior to discharge into the building ventilation system, the process off-gas containing primarily nitrogen and hydrogen is diluted with air. Under normal operating conditions, the hydrogen air-dilution system will dilute the hydrogen below 60% of its LEL. Under upset conditions, calculations indicate the hydrogen air-dilution system will dilute the hydrogen concentration to 3.4%, which is below the LEL of 4% for hydrogen. The design provides the following controls:

- Hydrogen air-dilution flow is continuously monitored. Airflow will be proven prior to startup. Loss of minimum airflow is interlocked for automatic shutdown of the hydrogen gas supply.

- A hydrogen gas detector is provided downstream of the hydrogen air-dilution system. Hydrogen detection will alarm at 25% of the hydrogen LEL and is interlocked for automatic shutdown of two hydrogen safety shutoff valves at 50% of the hydrogen LEL.

- Emergency power is provided for the hydrogen air-dilution blower motor.

- The base process offgas blower unit is nonsparking per NFPA 91, Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.

- The hydrogen air-dilution system piping and all equipment handling hydrogen is metal and grounded or bonded.

- The nitrogen purge system is monitored for minimum pressure and flow and is interlocked with the hydrogen supply. In addition, a redundant nitrogen supply is provided and sized to provide sufficient purging of hydrogen gas from all systems.

- An oxygen sensor downstream of the base process off-gas scrubber is interlocked to shut off the hydrogen supply to the calciner. The oxygen analyzer is set to ensure action is taken before the oxygen concentration reaches 5% by volume as indicated in Table C.1(a) of NFPA 69, *Explosion Prevention Systems*.

- A nitrogen purge for tanks venting to the base process off-gas scrubber to ensure oxygen does not enter the base process off-gas system from the tanks and to prevent hydrogen from being drawn into the tanks.

- A pressure transmitter to detect loss of negative pressure in the calciner, interlocked to shutdown hydrogen flow.

- High and low hydrogen supply pressure sensors, interlocked to shut down double block hydrogen safety shutoff valves upon activation.

- Hydrogen detectors at the ceiling above the envelope of the calciner, calciner process off-gas filter, or the base process off-gas condenser and scrubber. Hydrogen detectors are interlocked to shut down double block hydrogen safety shutoff valves upon activation.

- An excess flow valve in the gaseous hydrogen supply line near the bulk hydrogen storage system.

Recirculating Air Heating, Ventilation, and Air Conditioning Units

The HVAC system for the Office Area is a recirculating air system. An air-handling unit will be mounted on the roof of the Office Area to provide heating, ventilation, and air conditioning for the Office Area. The system is designed for a 4100 CFM supply fan capacity with 1750 CFM of filtered outside air. Two boilers will provide hot water and an air-cooled water chiller will provide cooled water to the coils in the air-handling unit. Prefilters and final filters will be provided. The ventilation ducting is noncombustible material, and smoke detectors are provided in the air-handling unit.

The HVAC system for the process area is a HEPA filtered recirculating system. An air-handling unit will be located on the roof of the Office Area to provide heating, ventilation, and air conditioning for the process area. The system is designed for a 29,400 CFM supply fan capacity with 6400 CFM of filtered outside air. Prefilters and final filters will be provided. HEPA filters with a UL 900 Class 1 rating will be used. A ventilation supply duct extends through a 3-hour fire barrier separating the Office Area and the process area to provide heat, ventilation and air conditioning for the Intermediate Area and the adjoining room located north in the first floor Office Area. Other ventilation ducts and air transfer grills also extend through the 3-hour fire barrier. Curtain fire dampers are provided in ventilation openings in the 3-hour fire barrier. These fire dampers are Underwriters Laboratories listed with a 3-hour fire rating. The same boilers and air-cooling water chiller serving the Office Area air-handling unit will provide heated and cooled water to the coils in the air-handling unit for the process area. The ventilation ducting is noncombustible material, and smoke detectors are provided in the air-handling unit.

The smoke detectors provided in the air-handling units are listed for use in air distribution systems and are located per Section 6.4.2.1 of NFPA 90A, *Installation of Air-Conditioning and Ventilation Systems.* These systems are interlocked to shut down the air-handling units upon activation.

The pre-filters and final filters provided for the air-handling units meet Underwriters Laboratory Class 1 criteria per Section 5.9.3.1 of NFPA 801, *Fire Protection for Facilities Handling Radioactive Materials.*

Ventilation Systems – Effluent Processing Building

HVAC systems for the EPB are installed in accordance with NFPA 90A, *Installation of Air-Conditioning and Ventilation System* and NFPA 91, *Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.* This includes fan units for ventilation from the ammonia scrubber or room ventilation for the ammonia recovery area. Also, ventilation ducting is constructed of noncombustible material.

Fire Separation

Fire Separation – Oxide Conversion Building

The Office Area of the OCB is classified as a Group B – Business Occupancy per the 1999 Standard Building Code (SBC). This area is separated from the remainder of the facility by minimum 2-hour fire rated construction. The Conversion Area is enclosed by 3-hour fire rated construction. The first and second floor Office Areas, the Waste Handling Area and the Loading Area are all separated from the Conversion Area by 3-hour fire barriers. Dampers with a 3-hour fire rating are provided to protect ventilation openings. Door penetrations and utility penetrations will also be protected to provide minimum 3-hour fire duration.

The process area of the OCB is classified as a Group H-4 occupancy based on the limited volume of the process equipment and the provision of the double safety shutoff valves interlocked to several monitoring devices and the provision of an excess flow shutoff valve to isolate the bulk hydrogen supply (see Process Off-Gas System discussion).

Fire Separation - Effluent Process Building

The EPB is a Type IV-Unprotected construction and located within approximately 21 feet of the west wall of the Waste Handling Area and Electrical Room in the OCB. The assumed property line between the EPB and the OCB is approximately 3 feet from the exterior wall of the EPB. To comply with building separation requirements identified in Table 600 of the Standard Building Code, the east wall of the OCB is constructed as a 1-hour fire barrier with openings protected to provide a minimum ¾-hour fire resistance.

Transient Combustibles

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

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. To prevent hot metal particles from grinding and welding operations being pulled into a HEPA filter unit, a spark arrestor is provided in the ventilation duct from the grinding and welding operations located in the Waste Handling Area. The spark arrester is located upstream of any HEPA filter unit. NFS has a hot work program which requires a permit.

External Ignition and Fire Sources

Outside north wall of the Oxide Conversion Building

The existing UNB is located approximately 25 feet north of the OCB. The UNB is identified as Type IV construction per the Standard Building Code. Exterior walls of the UNB are constructed of metal attached to a rigid steel frame (noncombustible construction). The building is fully protected by automatic sprinkler protection. Since the UNB and the OCB will be separated as required to meet requirements identified on Table 600 in the Standard Building Code, no fire exposure is considered to exist between the two facilities.

Outside north wall of the Effluent Process Building

The Bulk Chemical Storage Area is to be located approximately 15 feet north of the EPB. Two carbon steel silos for storing cement and clay are also located adjacent the north wall at the northwest corner. In addition, a natural gas fire boiler is located under the canopy adjacent the north wall. With approximately 15 feet of separation between the Bulk Chemical Storage Area (located in containment dikes) and the EPB, no fire exposure is anticipated from the Bulk Chemical Storage Area to the EPB or from the EPB to the Bulk Chemical Storage Area. The two metal silos adjacent the north wall of the EPB used to store clay and cement do not present a fire exposure to the facility. However, the natural gas fired boiler under the north canopy could present a natural gas torch fire exposure and an explosion hazard to the building. If the boiler's burner management system is listed by a nationally recognized testing agency and if the natural gas supply is installed in accordance with NFPA 54, Natural Fuel Gas Code, a fire or explosion hazard resulting from the boiler and associated gas supply is considered to be highly unlikely.

Outside west wall of the Oxide Conversion Building and east wall of the Effluent Process Building

The assumed property line between the EPB and the OCB will be 3 feet-1 inch from the exterior wall of the EPB. The exterior walls of the OCB are constructed of pre-cast concrete panels and the exterior walls of the Effluent Process Building within 10 feet of the assumed property line are constructed with a 1-hour fire resistance rating with wall openings protected per the Standard Building Code. The two pedestrian openings to the second floor electrical room are protected by ¾-hour fire rated doors. Although the OCB is not fully sprinkled, combustible loading within the unsprinkled areas will be limited. The EPB is to be fully protected by an automatic sprinkler system. Since the Oxide Conversion Building and the EPB will be separated as required to meet requirements identified on Table 600 in the Standard Building Code, no fire exposure is considered to exist between the two facilities.

Outside west wall of the Effluent Process Building

CSXT railroad yard tracks are located approximately 140 feet west of the Effluent Process Building. The rail yard speed limit is 10 mph. All trains stop in the rail yard; there are no tracks that pass straight through. No maintenance or repairs of railcars are conducted in the rail yard. The bounding fire from a radiant heat exposure to the OCB and the EPB would be a liquefied propane gas (LPG) BLEVE. Maximum LPG railcar inventory is [redacted]allons. A BLEVE involves 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 generally presents insignificant thermal exposure to buildings because of the very short fireball duration. The likelihood of an initiating event leading to a railcar BLEVE or explosion is considered a very low likelihood.

Outside east wall of the Oxide Conversion Building

An access road for the BLEU Complex is located approximately 20 feet from east wall of the Oxide Conversion Building. The truck-loading canopy exposure fire bounds a vehicle exposure fire on the access road.

A [redacted]allon liquefied hydrogen tank is located approximately 100 feet southeast of the OCB. Since this bulk hydrogen system is installed in accordance with NFPA 50B, *Liquefied Hydrogen Systems at Consumer Sites*, the bulk hydrogen supply is not considered a fire exposure to the OCB.

Outside south wall of the Oxide Conversion Building and the Effluent Process Building

A metal canopy with all four sides open is located along the north side of the OCB and the southeast portion of the EPB. This canopy is not protected by a fire suppression system. Trucks will be staged under the canopy for loading. A fire involving a release of diesel fuel from a truck would result in structural damage to the Truck Loading Canopy. Based on the proposed arrangement of the Truck Loading Canopy with a minimum 10 feet of separation between the OCB and the area where trucks will be staged, flame spread back into the Loading Area is unlikely. This diesel pool fire would expose contents in the truck trailer to thermal damage. Fire modeling scenarios bound this fire exposure to the OCB.

To minimize the fire exposure from a truck located closer than 10 feet to the Oxide Conversion Building at the Truck Loading Canopy, exterior walls less than 10 feet from a truck at the Truck Loading Canopy are maintained as 1-hour fire barriers with penetrations protected to maintain the 1-hour fire duration (including automatic closing doors).

The Studsvik facility is located approximately 340 feet beyond the south side of the proposed metal canopy. The Studsvik facility consists of a rigid metal frame structure covered with metal siding. Based on activities conducted within the facility and the separation distance from the BLEU Complex, the Studsvik facility does not present a fire exposure to the BLEU Complex.

2.9.1.2. Fire Detection and Alarm

<u>Oxide Conversion Building</u>

A fire alarm panel is provided in the OCB integrated into the existing BLEU Complex fire alarm system. The fire alarm system is installed in accordance with Section 905 of the Standard Building Code and NFPA 72, *National Fire Alarm Code* for the OCB. This includes automatic activation of the alarm initiating appliances by the sprinkler water-flow device, smoke detection provided in the Electrical Room, the Conversion Area, air-handling units, and building process ventilation system, heat detection devices, and manual fire alarm stations. With exception of the exterior exit door from the first floor of the Conversion Area, manual fire alarm stations are located within 5 feet from exits per Section 905.1 of the Standard Building Code. Combination alarm indicating appliances with horn and strobe lights are provided throughout the OCB to notify occupants of emergencies.

<u>Effluent Processing Building</u>

An NFPA®72, *National Fire Alarm Code* compliant fire alarm signaling system is installed to meet Section 905 of the Standard Building Code and NFPA 101 for the EPB. The fire alarm system includes the following:

- Combination horn and strobe alarm indicating devices located throughout the EPB.
- Manual fire alarm stations, which includes one station at each of the required exit doors.
- A sprinkler water flow switch for the sprinkler riser, which when activated, will sound local alarms throughout the area and summon the fire emergency response team.
- Supervisory alarms including valve tamper for sprinkler system water control valves and alarm test valves.
- Alarms being transmitted to a constantly attended area.

2.9.1.3. Life Safety

Life safety exit doors, with illuminated exit signs, and panic hardware compliant with NFPA 101 are provided in the OCB and the EPB. The exit doors meet the maximum travel distances specified in the FHA. Egress pathways are marked and meet minimum widths specified in the FHA.

2.9.1.4. Fire Suppression

Automatic Fire Suppression - Oxide Conversion Building

A hydraulically designed wet type sprinkler system designed in accordance with NFPA 13 is provided in all areas of the OCB except the first and second floor areas of the Conversion Area and the Electrical Room. Sprinkler protection can not be provided in the first and second floors of the Conversion Area due to nuclear criticality safety concerns. The sprinkler system is designed as an Ordinary Hazard Group 2. The following specific design criteria have also been provided:

- Area of water application - 1,500 sq. ft.
- Minimum density - 0.20 gpm/sq. ft.
- Area per sprinkler - 100 sq. ft.
- Allowance for outside hydrants – 250 gpm

A water flow switch is provided at the sprinkler riser and connected to send an alarm signal to the fire alarm control panel located in the Electrical Room and a constantly attended location. Tamper switches on the sprinkler system control valve and wall post indicator valve are also connected to the fire alarm control panel to send supervisory alarm signals to a constantly attended location. Since closure of the alarm test valve can prevent activation of the water motor gong, the alarm test valve is electronically supervised per NFPA 72, *National Fire Alarm Code* requirements.

The sprinkler risers are to be located in the Waste Handling Area, the Loading Area, and the northeast corner of the first floor Mechanical Room. A water supply control valve, fire department connection, and water motor gong will be provided for each sprinkler riser.

Automatic Fire Suppression - Effluent Process Building

The EPB is to be fully protected by an automatic sprinkler system excluding the west canopy, the north canopy for the natural gas fired boiler, and the Electrical Room. Due to the large combustible loading from plastic tanks and vent lines, the sprinkler system is an Ordinary Hazard Group 2 system designed in accordance with NFPA 13, *Installation of Sprinkler Systems*. Control valves and alarm test valves are supervised with signals sent to a continuously monitored location. In addition, a water flow switch is provided to send an alarm signal to the continuously monitored location.

Portable Fire Extinguishers

Portable fire extinguishers are located throughout the OCB and the EPB. The type and size of fire extinguishers and maximum heights above floors are in accordance with NFPA 10, *Portable Fire Extinguishers.*

Fire Hydrants

Two fire hydrants are located at the BLEU Complex. These fire hydrants are supplied by a 6-inch branch water pipe extending from a looped 6-inch pipe along Carolina Avenue. One fire hydrant is located approximately 88 feet northeast of the OCB (Hydrant #1). The other fire hydrant is located approximately 100 feet north of the EPB (Hydrant #2). Fire Hydrants are dry barrel type with one 4½-inch outlet and two 2½-inch outlets. Water supply information for these two fire hydrants is as follows:

- Hydrant #1: Static – 98 psi, Residual – 64 psi, Flow 1,220 gpm.
- Hydrant #2: Static – 97 psi, Residual – 65 psi, Flow 1,230 gpm.

2.9.1.5. Fire Response

Primary fire response is from the Town of Erwin Fire Department, which has paid staff covering 24 hours/day and 7 days/week and paid volunteers on call. Response time to the BLEU Complex in full turnout gear would range from fifteen to twenty minutes.

2.9.1.6. Pre-Fire Plans

Detailed pre-fire plans for the BLEU Complex are available as required by Section 4.8 of NFPA 801, *Fire Protection for Facilities Handling Radioactive Materials.*

2.10 CRITICALITY DETECTION SYSTEM

NFS is required by NRC materials License SNM-124 to have a criticality accident detection and alarm system (CAAS) that meets the guidance in ANSI/ANS-8.3. This standard describes the requirements for power supplies and alarms.

The BLEU CAAS is not an IROFS, so the license requirements dictate the minimum necessary actions to ensure reliable operation of the CAAS. Further, the OCB and EPB design have rendered a criticality from any source "highly unlikely", so a failure of the CAAS due to loss of electrical power (due to a freak failure of equipment and external power supply) coincident with a criticality accident is not credible. Further, there are alarms that indicate if the CAAS has failed, which trigger appropriate responses per site procedures.

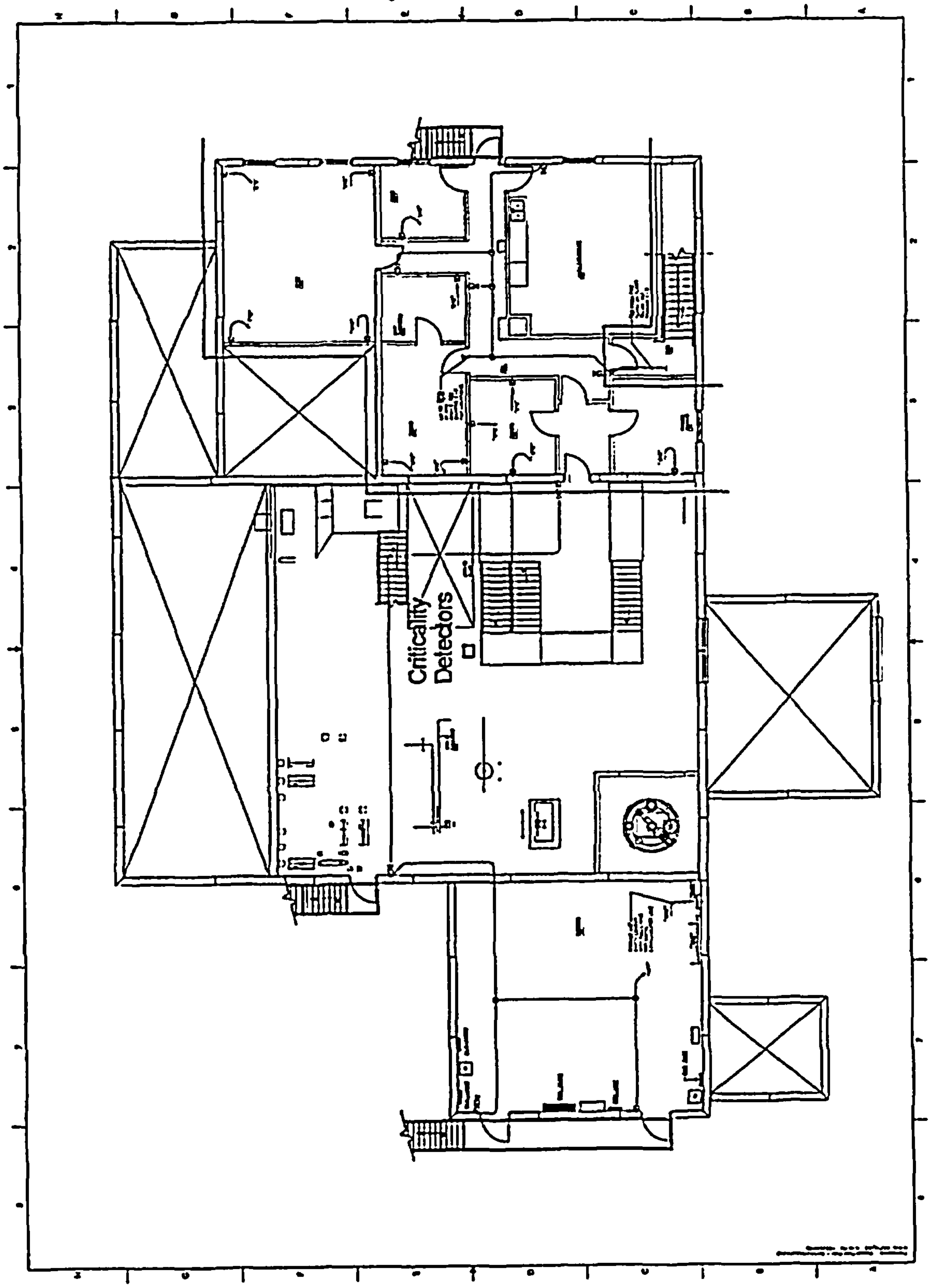
The BLEU Complex has a CAAS equipped with Eberline detectors. There are two detectors in operation in the UNB. There are two additional detectors in the

OCB conversion area. The criticality detector placement is provided on Figure 2-4. The OCB criticality detectors are tied into the existing system for the UNB.

The 120 VAC power supply to all detectors and audible alarms will be via the OCB UPS. This UPS double conversion (online) topology. The UPS fed by both normal and standby electrical power sources. The unit will generally be served from normal utility power; however during utility power failures, the UNB UPS will be served from the standby generator via the UNB transfer switch and the OCB UPS will be served from the standby generator via the OCB transfer switch. Back-up batteries will prevent power interruptions to the system during switching. The UPS will be installed with a manual bypass switch. This switch will be installed to allow manual transfer to either standby source. In the event that both normal and standby power are unavailable and the backup batteries are exhausted, a CAAS failure alarm will be activated in the Guard-Security Building. If this occurs, all movement of fissile material will be stopped. The criticality annunciator system is also powered via the UPS as described above.

In the unlikely event of a nuclear criticality accident, the alarm system would activate and all plant personnel would immediately evacuate their work area. 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 shutdown appropriate process equipment.

Figure 2-4
Criticality Detector/Readout Locations



3.0 PROCESS DESCRIPTIONS

The process operations for the conversion of the UN solution into uranium oxide powder are contained in two buildings on the BLEU Complex site. The UN is stored in the UNB in the BLEU Complex and is transferred to the OCB for processing. The major BLEU Complex uranium process operations are contained within the OCB. Process support operations for liquid waste and ammonia recovery are contained within the EPB. The major process operations in the OCB are dissolution, precipitation, ammonium diuranate (ADU) drying, ADU reduction in a calciner to produce uranium dioxide powder, and uranium recovery. The overall process flow diagram is provided in Figure 3-1. A set of process flow diagrams for the individual major process systems is provided in Appendix 1.

The process description section is made up of eight major sections (dissolution, precipitation, uranium recovery, dryer/calciner, oxide blending, ventilation, ammonia recovery and liquid waste). Each major section 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 each of the applicable safety perspectives. The Chemical and Radiological Safety sections address hazards to the worker whereas 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 eight 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 PRECIPITATION PROCESS

3.1.1 Process Description

3.1.2 Hazard Identification and Controls (Uranium Precipitation)

A summary table of hazards and controls for Uranium Precipitation is included as Table 3-1.

3.1.2.1. Criticality Hazards and Controls (Uranium Precipitation)

The uranium precipitation system incorporates passive and active engineered controls to ensure criticality safety, and compliance with the double contingency principle during operation of the system. The precipitation operation is performed in favorable geometry vessels and the equipment is spaced to control interaction.

The primary criticality safety hazards involve backflow of solution into unfavorable geometry UN Storage Tanks (within the UNB) and the utility supplies [deionized water (DIW), dilute nitric acid (DNA) and Ammonium Hydroxide (AH)]. Other criticality safety hazards involve spilling of uranium bearing material into the favorable geometry catch pans, the floor or into unfavorable geometry containers.

The safeguards for backflow of solution include a passive overflow line for all process vessels to direct overflow upsets to favorable geometries and equipping the utility supplies with active engineered controls to isolate the system if pressure is lost. For potential backflow of uranium from the ADU centrifuge into utility supplies, a three-way valve is credited.

Spills of uranium bearing material is not a normal event since during normal operation, uranium solution is contained within the precipitation system equipment. Initiating events, such as loss of level control in a process tank, could potentially lead to an upset condition, resulting in uranium solution overflowing a tank or vessel. Uranium solution could also leak from other parts of the system resulting in a spill. There are three possible consequences of uranium solution spills: the solution could accumulate in catch pans under each tank; it could overflow the catch pans and accumulate on the floor; or the solution could accumulate in an open container. There is no concern for criticality when uranium solution or uranium bearing material spills into the catch pan or onto the floor (favorable infinite slab geometry). Collection of uranium solutions in non-favorable geometry containers is prevented by restricting the use of such containers and further requiring all containers to be closed when unattended.

<u>Criticality Hazards:</u>

- Backflow into unfavorable geometry utility or chemical makeup supplies,
- Overflow of tanks or piping/equipment leaks into unfavorable geometry containers

Criticality Controls:

Passive Engineered Controls

- Passive overflows on vessels to favorable geometries (floor, catch pans, etc.)
- Chemically resistant favorable geometry metal containers, columns, and transfer pumps
- Utility and UN Tank supply lines installed at higher elevation than overflow lines
- Three-way valve for flow to ADU centrifuge
- Two independent overflow drains on blend and feed tanks to prevent backflow to UNB.

Active Engineered Controls

- Active interlocks on utility supplies to close supply valve when low pressure is sensed by pressure indicator transmitter
- Active interlocks on precipitator tank to close supply valve and shutoff transfer pumps when high level is sensed by high-high column level switch.

Administrative Controls

- Only favorable geometry containers allowed in area.
- Unattended containers in the area must not be left open.

3.1.2.2. Chemical Hazards and Controls – Worker (Uranium Precipitation)

Chemicals in the uranium precipitation process include:

- Uranyl Nitrate feed solution in dilute acidic solution (approximately 0.6 molar excess nitric acid).
- Ammonium Diuranate (ADU) slurry in dilute basic solution (approximately 0.2 molar excess ammonia).
- Aqueous ammonia solution (approximately 23% ammonia by weight).
- Ammonium nitrate in dilute aqueous solution (approximately 11% by weight).

Chemical Reactions:

Two chemical reactions occur in the precipitation process. The main reaction is to produce ADU by reacting UN with aqueous ammonia solution. This is done so that the ADU can be separated for further processing. Ammonium nitrate is produced as a byproduct, and is also produced in a side reaction as the excess nitric acid is reacted with aqueous ammonia. Excess aqueous ammonia solution is added so that the product is slightly basic.

$$2UO_2(NO_3)_2 + 6NH_4OH \rightarrow (NH_4)_2U_2O_7 + 4NH_4NO_3 + 3H_2O$$

$$HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$$

<u>Chemical Hazards:</u>

Chemical spills of all process solutions were analyzed. Spills of dilute process solutions of UN and ADU did not meet the threshold for intermediate or high consequences for worker exposure. Spills were analyzed for all process equipment and the worst case with respect to potential personnel exposure was taken as the limiting case.

A rupture of the ammonium hydroxide supply header was analyzed and found to have the potential to exceed the ERPG-3 level for worker exposure. Unmitigated, this has the potential to be a high consequence event. Supply header integrity is maintained by ensuring that proper materials of construction are used in the ammonium hydroxide header, that all welded construction is utilized and by periodic inspection to ensure that system components are properly maintained.

Ammonium nitrate is present in the process. Since it is not possible to predict the exact nature of damage to a potential detonation of ammonium nitrate, the occupational consequences were conservatively considered to be high.

Prior to the precipitation step, ammonium nitrate is present only in trace amounts well below 1% weight. At these low concentrations, there is no credible mechanism that would cause detonation of the ammonium nitrate, so what little is present is benign. During the precipitation step, ammonium nitrate is produced by the reaction of aqueous ammonia with UN and by the side reaction of aqueous ammonia solution with the excess acid in the UN solution. The product slurry contains approximately 11% ammonium nitrate by weight. Detonation is not considered to be a risk as long as the concentration of ammonium nitrate remains below 92% according to the Fire Protection Handbook. Even though the process solution is far below this concentration, the possibility exists that, due to operator error, a pump could be run dead-headed for a sufficient period of time to allow heat to build up and water to boil off until a critical concentration was reached. This is a slow process that would require many hours to transpire. In order to prevent this remote possibility, pumps have recirculation lines that circulate a portion of the solution back to the source tank to remove heat and prevent drying out of the pump. In addition, temperature alarms are provided to alert the operator well before the pump casing temperature climbs to the point where a critical concentration of ammonium nitrate could detonate.

In addition to the chemical hazards in the process itself, the process contains connections to other plant processes through the tank vent system piping.

Potentially hazardous interactions could occur if process solutions were allowed to enter the tank vent system. Overflows into the vent system are prevented by operator response to high level alarms, interlocks that shut off the feed sources to the tank in the event of a high level condition, and by tank overflow lines, where appropriate, to prevent misdirected flow into the tank vent piping.

Chemical Controls:

Passive Engineered Controls

- Compatible materials of construction
- Piping and vessels of welded construction
- Tank overflow lines
- Pump recirculation lines

Active Engineered Controls

- Tank high level interlocks to shut off feed flow

Administrative Controls

- Periodic inspections to ensure system components are properly maintained
- Tank high level alarms on the Central Control System (CCS)
- Pump casing high temperature alarms

Other provisions for managing the safe handling 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment and process controls, alarm and interlocks, are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.1.2.3. Radiological Hazards and Controls (Uranium Precipitation)

The uranium precipitation system uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the precipitation 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.

There are two radiological materials in the precipitation system. One is a UN (Class D) solution and the other is an ADU solution/slurry (Class W). These uranium compounds are enriched in the isotope U-235 and include the progeny of the isotopes of uranium as well as other radionuclides.

Radiological Hazards:

Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the ADU and the UN did not meet the criteria for intermediate or high consequences to either worker or an individual located outside the control area. The releases evaluated included thermal stress, explosive release (i.e., pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

Passive Engineered Controls

- Physical separation of precipitation components
- Dike containment

Active Engineered Controls

- HEPA filters
- Process Exhaust Ventilation Scrubber

Administrative Controls

- Personnel training and procedures
- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.1.2.4. Fire and Explosion Hazards and Controls (Uranium Precipitation)

<u>Fire Resulting from Heater Over-Temperature</u>

Heaters with low wattage will be used to heat the uranyl nitrate solution to as high as 140°F and to heat the ammonium hydroxide to as high as 100°F. Failure of the uranyl nitrate heater or the ammonium hydroxide heater may result in an ignition source to local combustible material but is not expected to damage the metal tanks and piping. A high temperature interlock is provided to shut off power to the uranyl nitrate heater if the temperature exceeds the high temperature set point.

<u>Fire Exposure to Process Equipment</u>

A fire involving transient combustibles or combustible process equipment (i.e. polypropylene ventilation lines) may damage process equipment where flames impinge on equipment. A combustible control program will be implemented to control transient combustibles and the process equipment is constructed of limited combustible materials. In addition, a hot work program will be implemented.

With exception of the Moderation Control Area and Electrical Room, automatic sprinklers are provided throughout the Oxide Conversion Building. Smoke detection is provided at the ceiling level in the Moderation Control Area and the Electrical Room. The smoke detection system is interlocked to shut down the double hydrogen safety shutoff valves on the exterior side of the facility. In addition, the conversion area is separated from the remainder of the facility by a 3-hour fire resistant barrier.

<u>Ventilation System</u>

With exception of some minor use of polypropylene piping where clear piping will be needed for visual observation, the ventilation system piping is constructed of noncombustible materials. The ventilation system is not repeated under the remaining individual process systems because it is treated here as a building issue.

The type of HEPA filter units used in the OCB has a maximum thermal operating temperature of 250°F. The HEPA filters meet the criteria of UL 900, Class 1, with frames constructed from wood treated with a fire retardant. Fire damage to the HEPA filters may occur if a transient combustible fire is within 4 feet of the HEPA filter unit. HEPA filter media may also be damaged if sparks or embers from a fire at a process hood are drawn into the ventilation system and contact the HEPA filter media and any combustible material collected on the filters. Assuming the HEPA filter unit is exposed to 50% of the maximum temperature for the upper thermal layer in the Conversion Area, no thermal damage effects are expected to this HEPA filter unit from the expected upper thermal layer temperatures. In addition, the fork truck propane torch fire will not damage the HEPA filter unit as long as a minimum 12 feet of separation is maintained between the fork truck and the filter unit.

Assuming the HEPA filter is only exposed to the lower thermal layer of a bounding fire scenario based on the height of the ceiling and the location of the HEPA filter, no thermal damage effects are expected to this HEPA filter unit from the expected lower thermal layer temperatures.

Nitric Acid 10% Concentration

Nitric Acid, at approximately 10% concentration is periodically used for acid flushing. Nitric Acid, at a 10% concentration is identified as a Class 1 oxidizer per NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers.* A Class 1 oxidizer does not significantly increase the burning rate of combustible materials with which it comes into contact.

Dilute Ammonium Nitrate Overheating by Deadheaded Pump

Based on Chapter 23 of Section 6, *Storage and Handling of Chemicals* in the Nineteenth edition of the National Fire Protection Association, Fire Protection Handbook, "Ammonium nitrate in water solution is not hazardous unless spilled into combustible material and permitted to dry. Research however, has shown that solutions containing up to 8 percent water can be detonated." Since the ammonium nitrate solution in the process does not exceed 10% ammonium nitrate (remaining 90% mostly water), the material is not expected to present a fire or explosion hazard. Although pump over-pressurization failures resulting from ammonium nitrate being overheated by churning in a pump for several days is a remote potential, temperature sensors interlocked to shut down pumps are provided at pumps where the diluted concentration of ammonium nitrate is normally present.

Fire or Explosion Hazards:

- Fire Resulting from Heater Over-Temperature
- Fire Exposure to Process Equipment
- Ventilation System
- Nitric Acid 10% Concentration
- Dilute Ammonium Nitrate Overheating by Deadheaded Pump

Fire or Explosion Controls:

Passive Engineered Controls

- Majority of process equipment constructed of noncombustible materials.
- Majority of ventilation system constructed from noncombustible materials.
- A 3-hour rated fire barrier separating unsprinklered process area from remainder of facility.

- UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant.

Active Engineered Controls

- Over-temperature shutdown controls on the uranyl nitrate heater.
- Temperature monitoring of heaters.
- Automatic sprinkler system coverage in Tank Gallery.
- Smoke detection interlocked to close the double hydrogen safety shutoff valves upon activation.
- Low wattage heaters.
- Over-temperature shutdown controls for pumps where dilute concentrations of ammonium nitrate may be present under normal operating conditions.

Administrative Controls

- Combustible control program.
- Hot work program.

3.1.2.5. Environmental Hazards and Controls – Public (Uranium Precipitation)

The environmental hazards for the OCB BLEU Uranium Precipitation 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. For the Uranium Precipitation process the following chemical hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions. The environmental radiological hazards and controls for Uranium Precipitation are presented in Section 3.1.2.3.

The OCB building is designed to contain all process spills from the uranium precipitation process. Public exposure to process upsets in the uranium precipitation process is therefore limited to the exposure to exhaust fumes from the building that are generated by process upsets involving potentially hazardous materials.

Potential public exposure due to a process upset was examined for each potentially hazardous chemical in the process. The potential exposure was taken to be the highest downwind concentration under the worst case atmospheric conditions. Only two cases examined had potential for intermediate or high consequence events due to public exposure. The first case was an ammonium hydroxide header leak which had the potential to exceed the ERPG-1 level for public exposure. The second case was in the event of an ammonium nitrate detonation. Since it is not possible to predict the exact nature of damage to a potential detonation, the environmental consequences were conservatively considered to be high. A detailed discussion of the postulated hazard scenarios and associated controls is given in Section 3.1.2.2.

Table 3-1
Hazard Summary for Precipitation Process

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• Backflow into unfavorable geometry utility or chemical makeup supplies, • Overflow of tanks or piping/equipment leaks into unfavorable geometry containers	• Passive overflows on vessels to favorable geometries (floor, catch pans, etc.) • Chemically resistant favorable geometry metal containers, columns, and transfer pumps • Utility and UN Tank supply lines installed at higher elevation than overflow lines • Three-way valve for flow to ADU centrifuge • Two independent overflow drains from UN Tank supply	• Active interlocks on utility supplies to close supply valve when low pressure is sensed by pressure indicator transmitter • Active interlocks on precipitator tank to close supply valve and shutoff transfer pumps when high level is sensed by high-high column level switch.	• Only favorable geometry containers allowed in area. • Containers in the area must not be left open and unattended
Chemical Worker	• Ammonium nitrate explosion • Exposure to ammonia fumes • Backflow of process solution into other systems	• Materials of const. • Piping and columns welded const. • Tank overflow lines prevent backflow • Pump recirculation lines prevent dead head operation	• Tank high level interlocks isolate feed valves	• Periodic inspections • Operator response to tank high level alarms • Operator response to pump casing high temperature alarms
Radiological	• Thermal stress • Explosive release (i.e. pressurized venting effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• Physical separation of precipitation components • Dike containment	• HEPA filters • Process Exhaust Ventilation Scrubber	• Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)
Fire and Explosion	• Fire Resulting from Heater Over-Temperature • Fire Exposure to Process Equipment	• Majority of process equipment constructed of noncombustible materials.	• Over-temperature shutdown controls on the uranyl nitrate	• Combustible control program. • Hot work program.

	• Ventilation System • Nitric Acid 10% Concentration • Dilute Ammonium Nitrate Overheating by Deadheaded Pump	• Majority of ventilation system constructed from noncombustible materials. • A 3-hour rated fire barrier separating unsprinklered process area from remainder of facility. • UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant	heater. • Temperature monitoring of heaters. • Automatic sprinkler system coverage in Tank Gallery. • Smoke detection interlocked to close the double hydrogen safety shutoff valves upon activation.. • Low wattage heaters. • Over-temperature shutdown controls for pump where dilute concentrations of ammonium nitrate may be present under normal operating conditions.	
Environmental chemical	• Ammonium nitrate explosion • Exposure to ammonia fumes	• Materials of const. • Piping and columns welded const. • Pump recirculation lines prevent dead head operation	• None	• Periodic inspections • Operator response to pump casing high temperature alarms

3.2 URANIUM DRYER/CALCINER PROCESS

3.2.1 Process Description

Dryer and Calciner Operation

3.2.2 Hazard Identification and Controls (Uranium Dryer/Calciner)

A summary table of hazards and controls for **Uranium Dryer/Calciner** is included as **Table 3-2.**

3.2.2.1. Criticality Hazards and Controls (Uranium Dryer/Calciner)

The dryer/calciner system incorporates passive and active engineered controls to ensure criticality safety, and compliance with the double contingency principle during operation of the system. The dryer/calciner operation is performed in favorable geometry vessels and the equipment is spaced to control interaction.

The primary criticality safety hazards involve spilling of uranium bearing material onto the floor. During normal operation, ADU flows from the ADU centrifuge into the ADU dryer and then into the calciner where it is converted to UO_2. These are sealed systems that are designed to contain the uranium material inside the equipment. Initiating events, such as equipment failure or equipment breach, could potentially lead to an upset condition, resulting in ADU or UO_2 spilling from the equipment onto the floor. The uranium solids rheology is dependent on the water volume fraction. If sufficient water is present to be a criticality concern (>50 vol. %), the matrix is free-flowing and a credible spill will not exceed a safe slab depth. If the solids are > 50 vol. %, criticality is not a concern due to the large mass (>420 kg UO_2) that must be released and retained in a hemispherical configuration.

Also, the central vacuum system is used to collect loose uranium powder from equipment and hoods for further processing. Powder is accumulated in a favorable geometry container via a rotary valve. Upsets that could cause a potential criticality include spilling powder from a container or leaking powder from the collection vessel. However, calculations of credible spill scenarios based on the above uranium solids rheology show that there is no concern for criticality when UO_2 powder spills onto the floor or into the enclosure.
<u>Criticality Hazards:</u>

- Equipment failure or equipment breach into unfavorable geometry containers.

Criticality Controls:

Passive Engineered Controls

- Sealed systems that are designed to contain the uranium material inside the equipment,
- Chemically resistant favorable geometry metal containers and equipment.

Active Engineered Controls

- Container-in-position proximity switch to detect the presence of a favorable geometry collection container prior to activating the central vacuum system,
- Lid Down sensor indicates that a favorable geometry collection container is sealed to the transfer line prior to activating the central vacuum system,
- Rotary valve in central vacuum system below the receiver vessel must not activate until the container-in-position proximity switch is activated,
- Central vacuum system blower must not activate until the lid down sensor is activated.

3.2.2.2. Chemical Hazards and Controls – Worker (Uranium Dryer/Calciner)

Chemicals in the uranium dryer/calciner process include:

- Ammonia in process off gases
- Hydrogen in process off gases
- Nitrogen in process off gases

Chemical Reactions:

Two chemical reactions occur in the dryer/calciner process. The main reaction produces uranium dioxide (UO_2) powder by reducing the uranium with hydrogen in the calciner. A second reaction occurs in the calciner as ammonia is liberated from the ammonium diuranate (ADU) feed slurry. At high temperatures, some of the ammonia is broken down to nitrogen and hydrogen. This hydrogen then assists in the main reaction to produce calcined UO_2 powder. The reactions in the calciner are:

$$[(UO_3)\cdot X(NH_3)\cdot Y(H_2O)]_{(s)} + H_{2(g)} \rightarrow UO_{2(s)} + X(NH_3)_{(g)} + (Y+1)(H_2O)_{(g)}$$

$$2NH_{3(g)} \Leftrightarrow N_{2(g)} + 3H_{2(g)}$$

Chemical Hazards:

The chemical hazards associated with the dryer/calciner process are the result of chemicals in the off gas. Both the dryer and the calciner heat and dry the ADU slurry. In this process, ammonia is liberated both from the residual liquid that enters the process and in the calciner as a result of the breakdown of the ADU itself to produce UO_2 powder. Hydrogen is added to the calciner to reduce the uranium and additional hydrogen is produced from the decomposition of ammonia in the off gas. Most of the hydrogen in the process is consumed in the reduction reaction in the calciner, but some excess hydrogen is present in the off gas.

The potential effects of off gas leaks in the dryer and calciner were examined. The small amounts of ammonia liberated in the dryer were not enough to create the potential for intermediate or high consequences to the worker. In the calciner however, sufficient ammonia is present in the off gas to exceed the ERPG-2 level for ammonia to the worker in the event of a complete off gas leak to the room. Unmitigated, this has the potential to result in intermediate consequences. In addition, hydrogen is present in the calciner off gas. Due to the potential fire hazard associated with hydrogen, it was assumed that a major calciner off gas leak to the room would result in a fire. A fire in the room where the calciner is located was examined and determined to have the potential for high consequences to the worker. The limiting case was taken to be bounding, so a leak in the calciner off gas was considered to have the potential for high consequence to the worker.

The primary safeguard against off gas leaks is to ensure the integrity of the system boundaries. This is done by ensuring that compatible materials of construction are used for the materials handled. Periodic inspections ensure that the systems are properly maintained. In the unlikely event of a process upset that has the potential to cause an overpressurization of the calciner, alarms would alert the operator to allow corrective action to be taken. In addition, a high pressure interlock shuts off the gas flow to the calciner system in the event of overpressure, preventing hazardous off gases from venting to the room.

Normally, the calciner and dryer operate under slight vacuum conditions. For this reason, most foreseeable leaks would cause room air to be drawn into the system rather than off gas to leak out. Without an ignition source in the system, the inlet of air into the off gas would not result in any potential for occupational exposure. Only in the event of a large failure such as significant quantities of the off gas vented to the room would such adverse consequences be possible. In such an event, the room hydrogen monitors would initiate an interlock to shut the hydrogen supply valve and provide an additional measure of protection against high consequences resulting from a calciner off gas leak. In such an event, the off gas oxygen sensors would initiate an interlock to shut the hydrogen supply valve and provide an additional measure of protection against high consequences resulting from a calciner off gas leak.

Chemical Controls:

Passive Engineered Controls

- Compatible materials of construction

Active Engineered Controls

- Hydrogen supply interlock with system oxygen monitors
- Calciner high pressure interlocks to shut down the calciner

Administrative Controls

- Calciner high pressure alarms on the Central Control System (CCS)
- Periodic equipment inspections

Other provisions for managing the safe handling 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment; and, process controls, alarm and interlocks are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.2.2.3. Radiological Hazards and Controls (Uranium Dryer/Calciner)

The uranium dryer/calciner uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the dryer/calciner 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.

There are two radiological materials in the dryer/calciner system. One is an ADU solution/slurry (Class W) and the other is UO_2/U_3O_8 powder (Class Y). These uranium compounds are enriched in the isotope U-235 and include the progeny of the isotopes of uranium as well as other radionuclides.

<u>Radiological Hazards:</u>

Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the ADU and the UO_2/U_3O_8 did not meet the criteria for intermediate or high consequences to either worker or an individual located outside the control area. The releases evaluated included thermal stress, explosive release (i.e., pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

<u>Radiological Controls:</u>

<u>Passive Engineered Controls</u>

- Physical separation of dryer/calciner components
- Vented vessel (calciner)
- Dike containment

<u>Active Engineered Controls</u>

- Oxygen analyzer downstream of off-gas scrubber
- High/low hydrogen pressure interlocked with hydrogen supply valves
- Vacuum-pressure system blower
- Hydrogen-air dilution blower
- Hydrogen gas detector downstream of air-dilution system
- HEPA filters
- Process Exhaust Ventilation Scrubber

<u>Administrative Controls</u>

- Dryer pressure indication

- Calciner pressure indication
- Personnel training and procedures
- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.2.2.4. Fire and Explosion Hazards and Controls (Uranium Dryer/Calciner)

Equipment Damage or Fire Due to Heater Over-Temperature

Electric heaters are provided for the ammonium diuranate dryer and the calciner. Independent over-temperature interlocks are provided to shutdown power to the heaters upon over-temperature detection. Heaters with low wattage are also provided for the calciner off-gas pipe and the ammonium diuranate dryer and calciner filters. Failure of the calciner off-gas heater or a filter heater may result in an ignition source to local combustible material but is not expected to damage the off-gas piping or filters.

Hydrogen Fire or Explosion

A hydrogen and nitrogen atmosphere is used in the calciner to convert ammonium diuranate to uranium dioxide. The calciner is vented to the base process off-gas system, which discharges to the building exhaust. Hydrogen will be delivered to the calciner at a maximum pressure of 5 psig and maximum flow rate of 10 scfm through schedule 80 stainless steel piping. To ensure failure of a regulator does not result in pressures over 5 psig within the building and to help detect leaks in the hydrogen supply line, a high and a low hydrogen gas pressure sensor is provided and interlocked to close the two hydrogen safety control valves on the exterior side the facility. In addition, an excess flow valve is provided in the gaseous hydrogen supply line near the bulk hydrogen supply system.

Loss of the primary nitrogen supply may result in a pressure imbalance and air leakage into the calciner which could result in a hydrogen mixture within its explosive range. Also with loss of the nitrogen supply, other process equipment, such as the ammonium diuranate dryer would not be maintained under a nitrogen purge potentially allowing oxygen to enter the base process off-gas system. Since the nitrogen supply is required to purge the hydrogen from the system, a redundant means is provided for purging hydrogen from the process and process off-gas equipment upon loss of the main nitrogen supply. In addition, a low nitrogen pressure and low nitrogen flow sensor will be provided and interlocked to shut off the process hydrogen valve.

A hydrogen release from process or process off-gas equipment into the process area could potentially result in hydrogen collecting within its explosive range at the ceiling. Ignition of a collection of hydrogen under the ceiling would result in an explosion with building and process damage. To prevent hydrogen releases from the calciner and the base process off-gas system, the calciner and base process off-gas system is maintained under a slight negative pressure. To ensure the negative pressure is maintained, a pressure sensor is provided at the calciner. This pressure sensor is interlocked to shutoff the process hydrogen supply valve. Also, hydrogen detectors are provided at the ceiling level as directed by a Fire Protection Engineer and interlocked to shut down the double hydrogen safety shutoff valves on the exterior of the building. The combustible gas detectors alarm in the CCS. In addition, to reduce the possibility of a hydrogen release being ignited at the ceiling, electrical equipment above the envelope of process equipment and within 3 feet of the ceiling is Class 1, Division 2, Group B.

If a hydrogen release to the process area is ignited immediately, the hydrogen fire may go undetected until the flame burns an occupant or the flame ignites adjacent combustibles. To detect and mitigate a hydrogen torch fire in the process area, a line-type heat detection system is provided as directed by a Fire Protection Engineer and interlocked to shut down the double hydrogen safety shutoff valves on the exterior of the building.

Since the calciner is operated above the autoignition temperature of hydrogen, a fire will be present within the calciner at any point where air leaks into the calciner and the calciner is at or above the autoignition temperature for hydrogen. To address this issue, the high temperature interlock to shut down the heaters for the calciner is arranged to shut off the process hydrogen valve.

The calciner off-gas containing ammonia vapors, hydrogen, and nitrogen will cool below the autoignition temperature of hydrogen shortly after leaving the calciner. At this point, air leakage into the process off-gas system may result in sufficient oxygen to develop a hydrogen mixture within its explosive range. To detect excess oxygen in the base process off-gas system prior to entering the building process exhaust and to ensure being diluted well below 25% of the LEL for hydrogen, an oxygen sensor is provided downstream of the base process off-gas scrubber and interlocked to shut off the process hydrogen valve. At this point the hydrogen will be diluted well below 25% of its LEL. To ensure the hydrogen is properly diluted below 25 % of its LEL, an airflow sensor is provided to ensure the blower is providing adequate exhaust duct air flow for dilution. In addition, a hydrogen detector is provided in the same duct. The combustible gas detectors alarm in the CCS. Both the airflow sensor and the hydrogen detector are interlocked to shut down the process hydrogen valve.

<u>Fire Exposure to Process Equipment (Refer to Section 3.1.2.4)</u>

<u>Hood Enclosures</u>

The Add Back Hood and Central Vacuum Collection Station Hood will be LEXAN™ or equivalent polycarbonate material.

Based on the General Electric (GE) LEXAN™ MR 10 data sheet, LEXAN™ has a thermal deformation temperature of 270°F and undergoes thermal degradation and piloted ignition at 873°F, with an autoignition temperature of 1,076°F.

LEXAN™ is a polycarbonate composition sheeting. Maximum temperature for continuous service is 200°F. Melting point is 280°F. Polycarbonate has a UL 74 V-2 flame resistance rating.

LEXAN™ burns much slower than polymethyl methacrylate (PMMA), (commercially known as Plexiglas™) with less than one-third the heat release rate. The combustion is more of a smoldering nature with limited flaming and presents much less of a fire hazard than PMMA. The fire hazard analysis indicates that a fire involving a hood constructed of a polycarbonate material is bounded by the fire modeling.

Ventilation (Refer to Section 3.1.2.4)

Uranium Dioxide and U_3O_8 Powder

Uranium trioxide and U_3O_8 powder are considered noncombustible. Uranium dioxide can undergo an exothermic reaction to form U_3O_8. Although the reaction will give off heat, flaming and smoldering of the uranium oxide is not expected.

Nitric Acid 60% Concentration

Nitric acid at a maximum 60% concentration is used for dissolving scrap uranium powder in the first floor Conversion Area. Nitric acid at a maximum 60% concentration is categorized as a Class 2 oxidizer by NFPA 430A, *Storage of Liquid and Solid Oxidizing Materials*. The fire hazard for a Class 2 oxidizer is that it may cause a moderate increase in the burning rate of combustible material with which it comes into contact. In order to mitigate the fire hazard in the process areas, a combustible control program will be implemented. Since there will be limited transient combustibles within the process areas where transient combustibles could come into contact with a release of nitric acid, the fire hazard analysis indicates that fire modeling is considered to bound a fire involving transient combustibles coming into contact with nitric acid at a maximum concentration of 60%.

Fire or Explosion Hazards:

- Fire Resulting from Heater Over-Temperature
- Hydrogen Fire or Explosion
- Fire Exposure to Process Equipment
- Hood Enclosure
- Ventilation System

- Uranium Dioxide Powder
- Nitric Acid 60% Concentration

<u>Fire or Explosion Controls:</u>

<u>Passive Engineered Controls</u>

- Majority of process equipment constructed of noncombustible materials.
- Majority of ventilation system constructed from noncombustible materials.
- A 3-hour rated fire barrier separating unsprinklered process area from remainder of facility.
- Grounding and bonding of process equipment containing hydrogen.
- Add Back Hood and Central Vacuum Collection Station Hood constructed of LEXAN™ or equivalent polycarbonate material.
- UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant.
- Low wattage heaters for the calciner off-gas pipe and the ammonium diuranate dryer and calciner filters.

<u>Active Engineered Controls</u>

- Over-temperature shutdown controls for the ammonium diuranate dryer and calciner heaters.
- Temperature monitoring of heaters.
- Smoke detection interlocked to close the double hydrogen safety shutoff valves.
- Oxygen sensor interlocked to shut the process hydrogen valve.
- High and low hydrogen gas pressure sensors interlocked to close the double hydrogen safety shutoff valves.
- Excess hydrogen flow valve.
- Redundant means to purge hydrogen from process equipment.
- Low nitrogen purge pressure and flow rate sensors interlocked to shut the process hydrogen valve.
- Hydrogen detection at ceiling of process area and downstream of where the base process off-gas system enters the building process off-gas system

interlocked to alarm at 25% of the LEL for hydrogen and close the double hydrogen safety shutoff valves at 50% of the LEL. Conbustible gas detectors remotely report to a continuously manned station.

- Line-type heat detection system interlocked to close the double hydrogen safety shutoff valves.

- Air flow monitor for the building process off-gas system interlocked to close the double hydrogen safety shutoff valves upon loss of adequate air flow to maintain the concentration of hydrogen below 25% of its LEL.

- Pressure switch to monitor negative pressure in calciner interlocked to shut the process hydrogen valve.

- High temperature interlock for calciner be arranged to shut off the process hydrogen valve.

Administrative Controls

- Combustible control program.

- Hot work program.

3.2.2.5. Environmental Hazards and Controls – Public (Uranium Dryer/Calciner)

The environmental hazards for the OCB BLEU Uranium Dryer/Calciner 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. For the Uranium Dryer/Calciner Process the following chemical hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions. The environmental radiological hazards for the Uranium Dryer/Calciner are presented in Section 3.2.2.3.

Public exposure to process upsets in the dryer/calciner process is limited to the exposure to exhaust fumes from the building that are generated by process upsets involving potentially hazardous materials. Evaluations were done on potential public exposure in the event of complete venting of dryer and calciner off gases to the environment. This situation could result from a major leak in the off gas system, or from failure of the off gas treatment scrubbing process. In neither case did the potential exposure to hazardous chemicals in the process result in potential for intermediate or high consequence events.

In the event of a major off gas leak to the room that resulted in a fire, potential exists for the release of hazardous chemicals from other parts of the process. Were this to occur, the potential exists for concentrations of ammonia to exceed the ERPG-1 level to the public. Unmitigated, this could result in an intermediate consequence event. In order to prevent such a scenario, the primary means of defense is to prevent the fire by preventing the release of combustible gases from the calciner to the room as discussed in Section 3.2.2.2.

Table 3-2
Hazard Summary for the Dryer/Calciner Process

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• Equipment failure or equipment breach into unfavorable geometry containers	• Sealed systems that are designed to contain the uranium material inside the equipment, • Chemically resistant favorable geometry metal containers and equipment	• Container-in-position proximity switch to detect the presence of a favorable geometry collection container prior to activating the central vacuum system, • Lid Down sensor indicates that a favorable geometry collection container is sealed to the transfer line prior to activating the central vacuum system, • Rotary valve in central vacuum system below the receiver vessel must not activate until the container-in-position proximity switch is activated, • Central vacuum system blower must not activate until the lid down sensor is activated.	• None
Chemical Worker	• Release of toxic ammonia fumes from calciner off gas piping or equipment • Release of flammable hydrogen from calciner off gas piping or equipment	• Compatible materials of construction	• Calciner high pressure interlocks to shut down the calciner • Hydrogen supply interlock with system oxygen monitors	• Periodic equipment inspections • Operator response to calciner high pressure alarms on the Central Control System (CCS)
Radiological	• Thermal stress • Explosive release (i.e. pressurized venting effects, shock/blast effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• Physical separation of dryer/calciner components • Vented vessel (calciner) • Dike containment	• Oxygen analyzer downstream of off-gas scrubber • High/low hydrogen pressure interlocked with hydrogen supply valves • Vacuum-pressure system blower • Hydrogen-air dilution blower • Hydrogen gas detector downstream of air-dilution system • HEPA filters • Process Exhaust Ventilation Scrubber	• Dryer pressure indication • Calciner pressure indication • Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Fire and Explosion	• Fire Resulting from Heater Over-Temperature • Hydrogen Fire or Explosion • Fire Exposure to Process Equipment • Hood Enclosure • Ventilation System • Uranium Dioxide Powder • Nitric Acid 60% Concentration	• Majority of process equipment constructed of noncombustible materials. • Majority of ventilation system constructed from noncombustible materials. • Fire barrier separating unsprinklered process area from remainder of facility. • Grounding and bonding of process equipment containing hydrogen. • Add Back Hood and Central Vacuum Collection Station Hood constructed of LEXAN™ or equivalent polycarbonate material. • UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant • Low wattage heaters for the calciner off-gas pipe and the ammonium diuranate dryer and calciner filters.	• Over-temperature shutdown controls for the ammonium diuranate dryer and calciner heaters. • Temperature monitoring of heaters. • Smoke detection interlocked to close the process hydrogen shutoff valve. • Oxygen sensor interlocked to shut the process hydrogen valve. • High and low hydrogen gas pressure sensors interlocked to close the process hydrogen valve. • Excess hydrogen flow valve. • Redundant means to purge hydrogen from process equipment. • Low nitrogen purge pressure and flow rate sensors interlocked to shut the process hydrogen valve. • Hydrogen detection at ceiling of process area and downstream of where the base process off-gas system enters the building process exhaust and interlocked to alarm at 25% of the LEL for hydrogen and close the double hydrogen safety shutoff valves at 50% of the LEL. • Line-type heat detection system interlocked to close the double hydrogen safety shutoff valves. • Air flow monitor for the building process exhaust duct interlocked to close the process hydrogen valve upon loss of adequate air flow to maintain the concentration of hydrogen below 25% of its LEL. • Pressure switch to monitor negative pressure in calciner interlocked to shut the process hydrogen valve. • High temperature interlock for calciner be arranged to shut off the process hydrogen valve.	• Combustible control program. • Hot work program.

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Chemical Environmental	• Release of toxic ammonia fumes in the event of major fire from hydrogen leak from calciner off gas	• Compatible materials of construction	• Calciner high pressure interlocks to shut down the calciner • Hydrogen supply interlock with system oxygen monitors	• Periodic equipment inspections • Operator response to calciner high pressure alarms on the Central Control System (CCS)

3.3 URANIUM OXIDE BLENDING PROCESS

3.3.1 Process Description

3.3.2 Hazard Identification and Controls (Uranium Oxide Blending)

A summary table of hazards and controls for Uranium Oxide Blending is included as Table 3-3.

3.3.2.1. Criticality Hazards and Controls (Uranium Oxide Blending)

The oxide blending is designed for homogenization of UO_2 and U_3O_8 powders only. Additives, such as pore formers and die-lubricants, which are also moderators, are not used. The system incorporates passive and active engineered controls to ensure criticality safety, and compliance with the double contingency principle during operation of the system.

For a criticality accident to occur in the OCB oxide blending system, a relatively large amount of moderated powder must be collected in, or assembled into, an unfavorable geometry. Because all the components and vessels comprising the powder blending system are favorable geometry, with the exception of the weigh hopper and blender, the only credible locations for a criticality accident to occur is inside one or the other of these two vessels or outside the confines of the system (i.e., a powder spill). Design features and controls are employed to ensure that the amount of moisture in the powder remains below that necessary for a criticality to occur.

The criticality safety hazards of concern to the oxide blending system include:

- wet powder produced by the conversion process is introduced into the blending system
- external water ingress into the blending system
- a large spill, and subsequent moderation, of powder from the blending system
- significantly over loading the blender with powder at or near the allowed moisture limit

The safeguards to ensure that wet UO_2 powder from the conversion process is not transferred into the weigh hopper or blender include dual independent moisture analyzers. The calciner moisture analyzer prevents high moisture content powder from being discharged from the receiving hoppers to the weigh hopper and blender by disabling the rotary discharge valve, and turning off the blower used for vacuum transfer. The receiving hopper moisture analyzer also prevents the discharge of high moisture content powder by independently disabling the rotary discharge valve and closing an isolation valve in the vacuum transfer system. After wet powder is isolated inside the receiving hopper, and the vacuum transfer system is effectively shut down, the powder is then unloaded into a favorable geometry collection container. Proximity switches and interlocks ensure that the container is properly positioned to receive powder, before discharge can take place.

Further safeguards to ensure that UO_2 powder being transferred to the blending system remains dry (during transfer and while within the blending system) include: FANP operating experience that demonstrates the lack of water absorption during vacuum transfer using air; the use of a dry nitrogen (cryogenic supply) cover gas purge in the blender; the use of dry air (compressed air system) for oxidation of powder in the receiver hoppers; operation of valves, pneumatic actuators and, the process to storage container inflatable seals and the use of halocarbon oils for the blender drive system such that any leakage will not compromise criticality safety.

The safeguards to prevent the ingress of external water into the oxide blending system include double roofs above the ModCon area with water detection instrumentation between the two roofs and routine surveillance to detect leaks. The physical integrity and/or features of the oxide blending system further prevent external water from entering the system. Walls and/or physical barriers, berms, dikes, raised floors, elevated ventilation lines above the main line, or sealed penetration points of the ModCon area prevent the ingress of a stream or spay of liquid into the area. Operations (posted entrance) are further restricted to the amount of water (or other moderating liquid) that can be introduced into the ModCon area. To further prevent moderator entry, combustible materials (building components and trash) are minimized and only non-hydrogenous fire fighting means are employed in the ModCon area. Emergency response personnel are trained in the use of water to fight fires and the adverse effect of water related to criticality safety in moderation controlled areas.

Spills of uranium bearing material is not a normal event since during normal operation, uranium powder is contained within the blending system equipment. An operator must properly install the favorable geometry collection container, or product pail, to prevent the spillage of uranium powder during transfer. If these containers are not properly positioned then proximity and pressure switches will prevent the filling operation. The features of the ModCon area ensures that water does not come into contact with spilled powder.

The total mass of UO_2 powder in the blender is controlled such that any degree of moisture migration in the blender will not lead to a criticality. The blender arm in motion and dry nitrogen purge maintains moisture homogeneously mixed with powder and removes any evaporated moisture from blender.

<u>Criticality Hazards:</u>

- Migration of moderator to unfavorable geometry blending system
- Migration and accumulation of uranium and/or moderator in unfavorable geometry as a result of a spill

<u>Criticality Controls:</u>

<u>*Passive Engineered Controls*</u>

- Double roof above the ModCon area prevents the ingress of moderation
- Physical integrity of the oxide blending system prevents the ingress of moderation

- Physical barriers such as walls, berms, dikes, raised floors, sealed penetrations and elevated ventilation inputs prevent the ingress of moderation
- Dry nitrogen (cryogenic system) purge to blender to inhibit condensation of moisture
- Favorable geometry system components (weigh hopper and blender, excluded)

Active Engineered Controls

- Active interlocks on calciner to detect wet powder and prevent discharge by closing flow valve and prevent vacuum operation to blender
- Active interlocks on receiver hoppers to detect wet powder and prevent discharge by closing flow valve and prevent vacuum operation to blender
- Active interlocks on transfer station to detect the presence of the vacuum transfer vessel and maintain stop signal on high moisture to valve to prevent discharge unless favorable geometry container is in place
- Active interlocks on transfer station to prevent discharge unless the receiving vessel is in place, connected and properly sealed.
- Active interlocks on compressed air dryer system to remove residual moisture and prevent ingress into ModCon area.

Administrative Controls

- Entrance to the ModCon area posted to restrict the entry of water
- Entrance to the ModCon area posted to exclude the use of water to fight fires inside the ModCon area. The Emergency Control Director (ECD) must authorize the use of water to fight fires in any area
- Entrance to the ModCon area posted to restrict combustible storage inside the ModCon area
- Operator replaces the vacuum transfer vessel on high moisture with favorable geometry vessel to ensure that all wet powder is transfer to favorable geometry.
- Operator limits the blender oxide powder mass such that the total amount of water in the blender does not exceed the safety limit
- Operator maintains the blender arm in motion or dry nitrogen purge when the blender is filled to maintain moisture homogeneously mixed with powder or to remove evaporated moisture from blender

3.3.2.2. Chemical Hazards and Controls – Worker (Uranium Oxide Blending)

Chemicals in the uranium oxide blending process include:

- Nitrogen purge gas

<u>Chemical Reactions:</u>

One chemical reaction occurs in the oxide blending process. This reaction is to oxidize a portion of the calcined powder from UO_2 to U_3O_8. This is done for product quality reasons. The reaction is:

$$3UO_2 + O_2 \rightarrow U_3O_8$$

<u>Chemical Hazards:</u>

Nitrogen is added to the CP Receiver and Oxidizer vessels to ensure the powder remains dry and to facilitate moisture measurement for criticality control purposes. Nitrogen by itself is an asphyxiation hazard if sufficient quantities are present to displace oxygen. The flows involved in the process are on the order of liters per minute of gas into the process. This is negligible when compared with the size of the building and the rate of air changes.

The oxygen required for the oxidation reaction in the Oxidizer vessel is obtained by admitting air to the process. No source of pure oxygen is present. A heater is used to start the reaction and then the normal exothermic heat is used to maintain the reaction. The heat released is well below that which could reasonably be expected to cause damage to vessel containment. For this reason, there is not considered to be any credible chemical risk that would have the potential for intermediate or high consequences in this system.

<u>Chemical Controls:</u>

General provisions for managing the safe handling and use of hazardous chemicals are integrated into the processing of radioactive materials with potentially hazardous chemicals and processing of chemicals that are generated by chemical reaction during processing. These provisions include:

- 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment and process controls, alarm and interlocks, are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.3.2.3. Radiological Hazards and Controls (Uranium Oxide Blending)

The uranium oxide blending process uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the blender 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.

The one radiological material of concern in the blender is UO_2/U_3O_8 powder (Class Y). This uranium compound is enriched in the isotope U-235 and includes the progeny of the isotopes of uranium as well as other radionuclides.

Radiological Hazards:

Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Over pressurization of the blender has the potential to be a high consequence event due to worker exposure. Likewise, the over pressurization of the hopper has the potential for an intermediate consequence event due to worker exposure. Release of the UO_2/U_3O_8 powder did not meet the criteria for intermediate or high consequences to an individual located outside the control area. The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

Passive Engineered Controls

- Physical separation of blending components
- Vented vessel (hopper)
- Vented vessel (blender)
- Stainless steel material of construction (blender)
- Dike containment

Active Engineered Controls

- HEPA filters

- Process Exhaust Ventilation Scrubber

Administrative Controls

- Hopper pressure indication
- Blender pressure indication
- Personnel training and procedures
- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.3.2.4. Fire and Explosion Hazards and Controls (Uranium Oxide Blending)

Equipment Damage or Fire Due to Heater Over-Temperature

Low wattage electric heaters are provided for the calcined powder oxidizer vessel and the air supply to the calcined powder oxidizer vessel. Failure of the calcined powder oxidizer vessel heater or the air supply heater for the calcined powder oxidizer vessel may result in an ignition source to local combustible material but is not expected to damage the metal vessel or air supply line.

Fire Exposure to Process Equipment (Refer to Section 3.1.2.4)

Propane Fork Truck Fire

Plans are to use a propane powered fork truck to move product from the Loading Area to trailers under the Truck Loading Canopy. The fork truck is not to contain more than a maximum of 43 gallons of propane fuel. To minimize the potential of a propane cylinder BLEVE during a fire, the propane fuel cylinders used for the fork truck are constructed from steel. Light aluminum propane cylinders will not be used for the fork truck at the Oxide Conversion Building or the Effluent Process Building since test data indicates that this type of cylinder may BLEVE, after a short fire exposure duration.

Based on the fire hazard analysis, fire modeling indicates that within 12 feet of a directed propane fork truck torch fire, radiant heat could cause damage to equipment including the HF-2 HEPA filter unit. With the 3-hour fire rated door in the opening between the Loading Area and Conversion Area automatically closing as required, the HF-2 HEPA filter unit will not be exposed to this fire. No structural damage is expected in the Conversion Area or Loading Area and no damage to equipment containing hydrogen is expected based on the modeled bounding fire scenario.

Truck Fire at Loading Canopy

Trucks will be staged under the Truck Loading Canopy located adjacent the south side of the Oxide Conversion Building. The fire hazard analysis indicates a fire involving a diesel pool fire under the Truck Loading Canopy could result in structural damage to the Truck Loading Canopy. This diesel pool fire could also expose contents in the truck trailer to thermal damage. If the trucks are located at least 10 feet from the Oxide Conversion Building, fire spread into the Oxide Conversion Building is unlikely.

To minimize the fire exposure from a diesel pool fire, with fuel released from a truck under the Truck Loading Canopy, the exterior walls within 10 feet of trucks at the Truck Loading Canopy are to be maintained as 1-hour fire barriers with openings protected to maintain the 1-hour fire barrier (including automatic closing doors).

Hood Enclosures

The Pail Filling Hood will be LEXAN™ or equivalent polycarbonate material.

Based on the General Electric (GE) LEXAN™ MR 10 data sheet, LEXAN™ has a thermal deformation temperature of 270°F and undergoes thermal degradation and piloted ignition at 873°F, with an autoignition temperature of 1,076°F.

LEXAN™ is a polycarbonate composition sheeting. Maximum temperature for continuous service is 200°F. Melting point is 280°F. Polycarbonate has a UL 74 V-2 flame resistance rating.

LEXAN™ burns much slower than polymethyl methacrylate (PMMA), (commercially known as Plexiglas™) with less than one-third the heat release rate. The combustion is more of a smoldering nature with limited flaming and presents much less of a fire hazard than PMMA. The fire hazard analysis indicates that a fire involving a hood constructed of a polycarbonate material is bounded by the fire modeling.

Ventilation (Refer to Section 3.1.2.4)

Fire Due to Hot U_3O_8 Powder Contacting Combustible Materials

The calcined powder oxidizer vessel heater is used to heat the uranium oxide powder to approximately 250°C and the air supply heater for the calcined powder oxidizer vessel heats air to approximately 150°C to start the exothermic oxidation reaction of the uranium dioxide to U_3O_8. Since the reaction may reach a maximum temperature of approximately 500°C, ignition is expected for combustible materials that come into contact with an accidental release of hot U_3O_8 powder.

Uranium Dioxide and U_3O_8 Powder

Uranium trioxide and U_3O_8 powder are considered noncombustible. Uranium dioxide can undergo an exothermic reaction to form U_3O_8. Although the reaction will give off heat, flaming and smoldering of the uranium oxide is not expected.

Fire or Explosion Hazards:

- Fire Resulting from Heater Over-Temperature
- Fire Exposure to Process Equipment
- Propane Fork Truck Fire
- Truck Fire at Loading Canopy
- Hood Enclosure
- Ventilation System
- Fire Due to Hot U_3O_8 Powder Contacting Combustible Materials
- Uranium Dioxide and U_3O_8 Powder

Fire or Explosion Controls:

Passive Engineered Controls

- *Majority of process equipment constructed of noncombustible materials.*
- Majority of ventilation system constructed from noncombustible materials.
- The 3-hour rated fire barrier separating unsprinklered process area from remainder of facility.
- Pail Filling Hood constructed of LEXAN™ or equivalent polycarbonate material.
- UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant
- Low wattage heaters for the calcined powder oxidizer vessel and the air supply to the calcined powder oxidizer vessel.
- Use of steel propane cylinder for the Fork Truck.
- Exterior walls within 10 feet of trucks at the Truck Loading Canopy maintained as 1-hour fire barriers.

Active Engineered Controls

- Temperature monitoring of heaters.
- Smoke detection interlocked to close the double hydrogen safety shutoff valves.

- Administrative Controls
- Combustible control program.
- Hot work program.

3.3.2.5. Environmental Hazards and Controls – Public (Uranium Oxide Blending)

There are no chemical hazards to the environment for Uranium Oxide Blending. The environmental radiological hazards and controls for Uranium Oxide Blending are presented in Section 3.3.2.3.

Table 3-3
Hazard Summary for Oxide Blending

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• Migration of moderator to unfavorable geometry blending system • Migration and accumulation of uranium and/or moderator in unfavorable geometry as a result of a spill	• Double roof above the ModCon area prevents the ingress of moderation • Physical integrity of the oxide blending system prevents the ingress of moderation • Physical barriers such as walls, berms, dikes, raised floors, sealed penetrations and elevated ventilation inputs prevent the ingress of moderation • Dry nitrogen (cryogenic system) purge to blender to inhibit condensation of moisture • Favorable geometry system components (weigh hopper and blender, excluded)	• Active interlocks on calciner to detect wet powder and prevent discharge by closing flow valve and prevent vacuum operation to blender • Active interlocks on receiver hoppers to detect wet powder and prevent discharge by closing flow valve and prevent vacuum operation to blender • Active interlocks on transfer station to detect the presence of the vacuum transfer vessel and maintain stop signal on high moisture to valve to prevent discharge unless favorable geometry container is in place • Active interlocks on transfer station to prevent discharge unless the receiving vessel is in place, connected and properly sealed. • Active interlocks on compressed air dryer system to remove residual moisture and prevent ingress into ModCon area.	• Entrance to the ModCon area posted to restrict the entry of water • Entrance to the ModCon area posted to exclude the use of water to fight fires inside the ModCon area. The Emergency Control Director (ECD) must authorize the use of water to fight fires in any area • Entrance to the ModCon area posted to restrict combustible storage inside the ModCon area • Operator replaces the vacuum transfer vessel on high moisture with favorable geometry vessel to ensure that all wet powder is transfer to favorable geometry. • Operator limits the blender oxide powder mass such that the total amount of water in the blender does not exceed the safety limit • Operator maintains the blender arm in motion or dry nitrogen purge when the blender is filled to maintain moisture homogeneously mixed with powder or to remove evaporated moisture from blender
Chemical Worker	• No hazardous chemicals used in this portion of the process	• None	• None	• None

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Radiological	• Thermal stress • Explosive release (i.e. pressurized venting effects, shock/blast effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• Physical separation of blending components • Vented vessel (hopper) • Vented vessel (blender) • Stainless steel material of construction (blender) • Dike containment	• HEPA filters • Process Exhaust Ventilation Scrubber	• Hopper pressure indication • Blender pressure indication • Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)
Fire and Explosion	• Fire Resulting from Heater Over-Temperature • Fire Exposure to Process Equipment • Propane Fork Truck Fire • Truck Fire at Loading Canopy • Hood Enclosure • Ventilation System • Fire Due to Hot U3O8 Powder Contacting Combustible Materials • Uranium Dioxide and U3O8 Powder	• Majority of process equipment constructed of noncombustible materials. • Majority of ventilation system constructed from noncombustible materials. • Fire barrier separating unsprinklered process area from remainder of facility. • Pail Filling Hood constructed of LEXAN™ or equivalent polycarbonate material. • UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant • Low wattage heaters for the calcined powder oxidizer vessel and the air supply to the calcined powder oxidizer vessel. • Use of steel propane cylinder for the Fork Truck. • Exterior walls within 10 feet of trucks at the Truck Loading Canopy maintained as 1-hour fire barriers	• Temperature monitoring of heaters. • Smoke detection interlocked to close the double hydrogen safety shutoff valves.	• Combustible control program. • Hot work program.

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Chemical Environmental	• No hazardous chemicals used in this portion of the process	• None	• None	• None

3.4 URANIUM RECOVERY PROCESS

3.4.1 Process Description

3.4.2 Hazard Identification and Controls (Uranium Recovery)

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

3.4.2.1. Criticality Hazards and Controls (Uranium Recovery)

The uranium recovery system incorporates passive and active engineered controls to ensure criticality safety, and compliance with the double contingency principle during operation of the system. The recovery operation is performed in favorable geometry vessels and the equipment is spaced to control interaction.

The primary criticality safety hazards involve backflow of solution into unfavorable geometry utility supplies [deionized water (DIW), dilute nitric acid (DNA) and Ammonium Hydroxide (AH)] from both pressurized (ion exchange and cross flow filtration) and non-pressurized (receiving) process equipment. Other criticality safety hazards involve spilling of uranium bearing material into the favorable geometry catch pans, the floor or into unfavorable geometry containers.

The safeguards for backflow of solution from non-pressurized process equipment include a passive overflow line to direct overflow upsets to favorable geometries and equipping the utility supplies with active engineered controls to isolate the system if pressure is lost. The safeguards for backflow of solution from pressurized process equipment include equipping the utility supplies with dual independent active engineered controls to isolate the system if pressure is lost. Preventing backflow into the utility line and then further preventing backflow to the utility supply isolates the utility system.

Spills of uranium bearing material is not a normal event since during normal operation, uranium solution is contained within the recovery system equipment. Initiating events, such as loss of level control in a process tank, could potentially lead to an upset condition, resulting in uranium solution overflowing a tank or vessel. Uranium solution could also leak from other parts of the system resulting in a spill. There are three possible consequences of uranium solution spills: the solution could accumulate in catch pans under each tank; it could overflow the catch pans and accumulate on the floor; or the solution could accumulate in an open container. Criticality safety is ensured when uranium solution or uranium bearing material spills into the catch pan or onto the floor due to favorable infinite slab geometry. Collection of uranium solutions in non-favorable geometry containers is prevented by prohibiting non-favorable geometry containers from the area, restricting the use of such containers, and requiring all containers to be closed when unattended.

Criticality Hazards:

- Backflow into unfavorable geometry utility or chemical makeup supplies,
- Overflow of tanks or piping/equipment leaks into unfavorable geometry containers

Criticality Controls:

Passive Engineered Controls

- Passive overflows on vessels to favorable geometries (floor, catch pans, etc.)
- Chemically resistant favorable geometry metal containers, columns, and transfer pumps
- Utility supply lines installed at higher elevation than overflow lines

Active Engineered Controls

- Active interlocks on utility supplies to close supply valve when pressure indicator transmitter senses low supply pressure.
- Active interlocks on utility supplies to close process valve when pressure indicator transmitter senses low process pressure.

Administrative Controls

- Only favorable geometry containers allowed in area.
- Unattended containers in the area must not be left open.

3.4.2.2. Chemical Hazards and Controls – Worker (Uranium Recovery)

Chemicals in the uranium recovery process include:

- Centrifuge liquid containing dilute ammonium hydroxide.
- Ammonium nitrate in dilute aqueous solution (approximately 10% by weight).
- Ion exchanger regeneration chemicals including aqueous ammonia solution (approximately 23% ammonia by weight) and dilute nitric acid solution (approximately 10% by weight)

Chemical Reactions:

The only reactions that occur within the uranium recovery system are the reactions in the ion exchangers. There are no bulk chemical reactions in this process.

Chemical Hazards:

Chemical spills of all process solutions were analyzed. Some spills of dilute basic process solutions have the potential to exceed the ERPG-3 level for ammonia exposure. Unmitigated, this has the potential to be a high consequence event. Spills or leaks from tanks Tk-40, 43, 47B and the Ion Exchangers and associated piping were found to have the potential for high consequences. Leaks and ruptures are prevented by ensuring that the equipment is designed with compatible materials of construction and by periodic inspection to ensure equipment is properly maintained. In the case of tanks, overflow situations that have the potential for high consequences due to worker exposure to ammonia fumes are prevented by operator response to tank high level alarms and high level interlocks that shut down process feed flow in the event of a high level.

Ammonium hydroxide solution and dilute nitric acid are used in the uranium recovery process to regenerate the ion exchange beds. Use of these chemicals can present spill hazards and could also present a physical hazard if concentrated acid were inadvertently used to regenerate the ion exchange beds due to the potential for a violent reaction between the resin and concentrated acid. Protection against damage to the ion exchange resin or columns is provided by physical separation of the systems. The dilute acid system and concentrated acid systems are physically separate with separate headers and controls. No concentrated acid is used in the uranium recovery process. Only dilute acid is used. To prevent the inadvertent entry of concentrated acid into the dilute acid header during the dilute acid mixing process, interlocks are provided that isolate the dilute acid supply during mixing operations and isolates the concentrated acid supply on high concentration.

Spills of regeneration chemicals from their associated headers were analyzed. A rupture of the ammonium hydroxide supply header was analyzed and found to have the potential to exceed the ERPG-3 level for worker exposure. Unmitigated, this has the potential to be a high consequence event. Supply header integrity is maintained by ensuring that proper materials of construction are used in the ammonium hydroxide header, that all welded construction is utilized and by periodic inspection to ensure that system components are properly maintained. Spills of dilute nitric acid were also analyzed but potential consequences did not meet the threshold for intermediate or high consequences for worker exposure.

Ammonium nitrate is present in the process. Since it is not possible to predict the exact nature of damage to a potential detonation of ammonium nitrate, the occupational consequences were conservatively considered to be high.

The centrate liquid flow from the centrifuge contains approximately 10% ammonium nitrate by weight. Detonation is not considered to be a risk as long as the concentration of ammonium nitrate remains below 92% according to the Fire Protection Handbook. Even though the process solution is far below this concentration, the possibility exists that, due to operator error, a pump could be run dead-headed for a sufficient period of time to allow heat to build up and water to boil off until a critical concentration was reached. This is a slow process that would require many hours to transpire. In order to prevent this remote possibility, pumps have recirculation lines that circulate a portion of the solution back to the source tank to remove heat and prevent drying out of the pump. In addition, temperature alarms are provided to alert the operator well before the pump casing temperature climbs to the point where a critical concentration of ammonium nitrate could detonate.

In addition to the chemical hazards in the process itself, the process contains connections to other plant processes through the tank vent system piping. Potentially hazardous interactions could occur if process solutions were allowed to enter the tank vent system. Overflows into the vent system are prevented by operator response to high level alarms and interlocks that shut off the feed sources to the tank in the event of a high level condition.

Chemical Controls:

Passive Engineered Controls

- Compatible materials of construction
- Piping and vessels of welded construction
- Pump recirculation lines

Active Engineered Controls

- Tank high level interlocks to shut off feed flow

Administrative Controls

- Periodic inspections to ensure system components are properly maintained
- Tank high level alarms on the Central Control System (CCS)
- Pump casing high temperature alarms

Other provisions for managing the safe handling 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment and process controls, alarm and interlocks, are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.4.2.3. Radiological Hazards and Controls – Worker (Uranium Recovery)

The uranium recovery system uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the recovery 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.

The radiological material of concern in the uranium recovery system is an ADU solution/slurry (Class W). The ADU is enriched in the isotope U-235 and includes the progeny of the isotopes of uranium as well as other radionuclides.

Radiological Hazards:

Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the ADU did not meet the criteria for intermediate or high consequences to either worker or an individual located outside the control area. The releases evaluated included thermal stress, explosive release (i.e., pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

Passive Engineered Controls

- Physical separation of uranium recovery components

- Dike containment

Active Engineered Controls

- HEPA filters

- Process Exhaust Ventilation Scrubber

Administrative Controls

- Personnel training and procedures

- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.4.2.4. Fire and Explosion Hazards and Controls (Uranium Recovery)

Fire Exposure to Process Equipment (Refer to Section 3.1.2.4)

Ventilation (Refer to Section 3.1.2.4)

Nitric Acid 10% Concentration

Nitric Acid, at approximately 10% concentration, is periodically used for acid flushing and pH adjustment. Nitric Acid at a 10% concentration is identified as a Class 1 oxidizer per NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*. A Class 1 oxidizer does not moderately increase the burning rate of combustible materials with which it comes into contact.

Dilute Ammonium Nitrate Overheating by Deadheaded Pump (Refer to Section 3.1.2.4)

Fire or Explosion Hazards:

- Fire Exposure to Process Equipment
- Ventilation System
- Nitric Acid 10% Concentration
- Dilute Ammonium Nitrate Overheating by Deadheaded Pump

Fire or Explosion Controls:

Passive Engineered Controls

- Majority of process equipment constructed of noncombustible materials.
- Majority of ventilation system constructed from noncombustible materials.
- A 3-hour rated fire barrier separating unsprinklered process area from remainder of facility.
- UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant

Active Engineered Controls

- Automatic sprinkler system coverage in Tank Gallery and Natural Uranium Dissolver Room.
- Smoke detection interlocked to close the double hydrogen safety shutoff valves upon activation.

- Over-temperature shutdown controls for pumps where dilute concentrations of ammonium nitrate may be present under normal operating conditions.

Administrative Controls

- Combustible control program.

- Hot work program.

3.4.2.5. Environmental Hazards and Controls – Public (Uranium Recovery)

The environmental hazards for the OCB BLEU Uranium Recovery 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. For the Uranium Recovery Process the following chemical hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions. The environmental radiological hazards and controls for Uranium Recovery are presented in Section 3.4.2.3.

The OCB building is designed to contain all process spills from the uranium recovery process. Public exposure to process upsets in the uranium recovery process is therefore limited to the exposure to exhaust fumes from the building that are generated by process upsets involving potentially hazardous materials.

Potential public exposure due to a process upset was examined for each potentially hazardous chemical in the process. The potential exposure was taken to be the highest downwind concentration under the worst case atmospheric conditions. The only case examined that had the potential for intermediate or high consequences due to public exposure was in the event of an ammonium nitrate detonation. Since it is not possible to predict the exact nature of damage to a potential detonation, the environmental consequences were conservatively considered to be high. A detailed discussion of the postulated hazard scenarios and associated safeguards is given in Section 3.4.2.2.

Table 3-4
Hazard Summary for the Uranium Recovery Process

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• Backflow into unfavorable geometry utility or chemical makeup supplies, • Overflow of tanks or piping/equipment leaks into unfavorable geometry containers	• Passive overflows on vessels to favorable geometries (floor, catch pans, etc.) • Chemically resistant favorable geometry metal containers, columns, and transfer pumps • Utility supply lines installed at higher elevation than overflow lines	• Active interlocks on utility supplies to close supply valve when pressure indicator transmitter senses low supply pressure. • Active interlocks on utility supplies to close process valve when pressure indicator transmitter senses low process pressure.	• Only favorable geometry containers allowed in area. • Containers in the area must not be left open and unattended.
Chemical Worker	• Ammonium nitrate explosion • Exposure to ammonia fumes	• Materials of const. • Piping and columns welded const. • Pump recirculation lines prevent dead head operation	• Tank high level interlocks isolate feed valves	• Periodic inspections • Operator response to high tank high level alarms • Operator response to pump casing high temperature alarms
Radiological	• Thermal stress • Explosive release (i.e. pressurized venting effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• Physical separation of uranium recovery components • Dike containment	• HEPA filters • Process Exhaust Ventilation Scrubber	• Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Fire and Explosion	• Fire Exposure to Process Equipment • Ventilation • Nitric Acid 10% Concentration • Dilute Ammonium Nitrate Overheating by Deadheaded Pump	• Majority of process equipment constructed of noncombustible materials. • Majority of ventilation system constructed from noncombustible materials. • Fire barrier separating unsprinklered process area from remainder of facility. • UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant	• Automatic sprinkler system coverage in Tank Gallery and Natural Uranium Dissolver Room. • Smoke detection interlocked to close the double hydrogen safety shutoff valves upon activation. • Over-temperature shutdown controls for pump where dilute concentrations of ammonium nitrate may be present under normal operating conditions.	• Combustible control program. • Hot work program.
Chemical Environmental	• Ammonium nitrate explosion • Exposure to ammonia fumes	• Materials of const. • Piping and columns welded const. • Pump recirculation lines prevent dead head operation	• None	• Periodic inspections • Operator response to pump casing high temperature alarms

3.5 *URANIUM DISSOLUTION PROCESS*

3.5.1 Process Description

Natural Uranium Dissolution

3.5.2 Hazard Identification and Controls (Dissolution)

A summary table of hazards and controls for **Dissolution** is included as **Table 3-5**.

3.5.2.1. Criticality Hazards and Controls (Dissolution)

The scrap uranium dissolution system incorporates passive and active engineered controls to ensure criticality safety, and compliance with the double contingency principle during operation of the system. The scrap dissolution operation is performed in favorable geometry vessels and the equipment is spaced to control interaction. The natural uranium dissolution system incorporates passive and active engineered controls to ensure criticality safety (prevent the introduction of low enriched uranium), and compliance with the double contingency principle during operation of the system.

The primary criticality safety hazards involve backflow of LEU solution into the utility supplies [deionized water (DIW) and dilute nitric acid (DNA)], direct addition of LEU to the unfavorable natural uranium dissolution system or indirectly as a result of a process overflow resulting in solution accumulation in the ventilation system with subsequent backflow to the natural dissolution system. Other criticality safety hazards involve LEU solution leakage through a process heat exchanger and spilling of uranium bearing material into the favorable geometry catch pans, the floor or into unfavorable geometry containers.

The safeguards for backflow of solution include a passive overflow line for all process vessels to direct overflow upsets to favorable geometries and equipping the utility supplies with active engineered controls to isolate the system if pressure is lost. Translucent overflow/drain legs on tanks allow solution within the tank to drain to the floor or dissolution overflow tank and further allow overflow to the Scrubber prior to backflow of material to the Natural Dissolution Equipment. Independent high-level switch alarms also alert operators to an upset condition. Process off gas line elevation, above the overflow line, prevents backflow to the process ventilation system and the process off gas line further connects to the top of the process ventilation ductwork providing a passive engineered barrier. Active engineered pressure switches that automatically close the supply valves if a loss of supply pressure is detected in the supply lines provide additional backflow protection for the utility supply systems.

To prevent a direct addition of LEU to the natural dissolution process the equipment is kept in an isolated room of the OCB separate from the LEU processes. An enrichment monitor is provided and interlocked with the 55-gallon drum-loading crane to prevent movement of the drum if enriched material is detected. A proximity switch in the natural UO_3 powder feed enclosure prevents transfer of material into the natural dissolver if a 55-gallon drum is not detected. Natural powder is only handled in 55-gallon drums within the facility, whereas LEU powder is handled in dissimilar favorable geometry container (approximately 8" ID by 42" tall cylinder).

Due to the use of heat exchangers with uranium bearing solutions, the possibility exists that uranium may leak through the heat exchanger and into the unfavorable geometry cooling water supply system. To prevent this, the OCB uses a dual loop system with a favorable geometry secondary loop. The materials of construction of both heat exchangers are compatible with the solutions present in the system. To ensure that LEU solution will not get into the cooling water supply system, a conductivity monitor is installed in the primary cooling water loop. This conductivity monitor will detect the presence of the acidic LEU solution, indicating a leak across the primary heat exchanger. If the conductivity monitor detects a change in the cooling water, it is interlocked with the pumps for the uranium bearing solution side. This interlock will shut down the pumps, preventing further leaking across the heat exchanger and therefore making it unlikely that a criticality would occur from uranium leaking into the unfavorable geometry cooling water supply system.

Spills of uranium bearing material is not a normal event since during normal operation, uranium solution is contained within the dissolution system equipment. Initiating events, such as loss of level control in a process tank, could potentially lead to an upset condition, resulting in uranium solution overflowing a tank or vessel. Uranium solution could also leak from other parts of the system resulting in a spill. There are three possible consequences of uranium solution spills: the solution could accumulate in catch pans under each tank; it could overflow the catch pans and accumulate on the floor; or, the solution could accumulate in an open container. Criticality safety is ensured when uranium solution or uranium bearing material spills into the catch pan or onto the floor due to favorable infinite slab geometry. Collection of uranium solutions in non-favorable geometry containers is prevented by restricting the use of such containers and further requiring all containers to be closed when unattended.

Criticality Hazards:

- Backflow into unfavorable geometry utility or chemical makeup supplies,
- Overflow of tanks or piping/equipment leaks into unfavorable geometry containers, ventilation system or natural dissolution system,
- Direct addition of LEU to the natural dissolution system,
- Heat exchanger leakage into the unfavorable geometry cooling water supply system.

Criticality Controls:

Passive Engineered Controls

- Passive overflows on vessels to favorable geometries (floor, catch pans, etc.),
- Chemically resistant favorable geometry metal containers, columns, heat exchangers, and transfer pumps,
- Utility supply lines installed at higher elevation than overflow lines,
- Process off gas line elevation, above overflow lines prevents backflow to the process ventilation system,
- Process off gas line connections to the top of the process ventilation ductwork prevents potential backflow,
- Natural uranium powder is handled only in 55-gallon drums within the facility, whereas LEU powder is handled in dissimilar smaller containers constructed from 8-inch schedule 10 pipe,
- Natural uranium processing equipment is kept in an isolated room of the OCB building, separated from the LEU processes.
- Favorable geometry secondary cooling loop.

Active Engineered Controls

- Active interlocks on utility supplies to close supply valve when low pressure is sensed by pressure indicator transmitter,
- Active interlocks on cooling waterside of heat exchanger to shut down pumps when uranium-bearing solution is sensed by high conductivity monitor,

- Active interlocks on natural drum loading crane to prevent movement of drum if enriched material is detected,

- Active interlocks on natural UO_3 powder feed enclosure to prevent transfer into the natural dissolver if 55-gallon drum is not detected by proximity switch.

Administrative Controls

- Only favorable geometry containers allowed in LEU areas,

- Unattended containers in the area must not be left open and unattended,

- Clear, easy to read markings and color-coding of containers based on enrichment within the OCB emphasizes the importance to keep LEU and natural uranium separate,

- *Confirmation of shipper's data that 55-gallon drums contain only natural* uranium powder.

3.5.2.2. Chemical Hazards and Controls – Worker (Dissolution)

Natural Uranium Dissolution:

Chemicals in the natural uranium dissolution process include:

- Uranyl Nitrate (UNH) product solution in dilute acidic solution (approximately 0.5 molar excess nitric acid).

Chemical Reactions:

The natural uranium dissolution system dissolves natural uranium powder in nitric acid. To ensure the reaction is complete, excess acid is added. The product is a UNH solution with 0.5 molar excess nitric acid. Natural uranium (UO_3) is at the highest oxidation state for uranium, so no NOx is produced in the reaction. The reaction is performed in a batch reactor. The dissolution reaction is:

$UO_3 + 2HNO_3 \rightarrow UO_2\,(NO_3)_2 + H_2O + \text{Heat}$

Chemical Hazards:

Spills and fumes from the process solution were considered. Spills of batch or product solutions did not meet the threshold for intermediate or high consequences for worker exposure. Spills were analyzed for all process equipment and the worst case with respect to potential personnel exposure was taken as the limiting case.

Another hazard, unique to the natural dissolution process, is the possibility of inadvertently adding a drum of scrap uranium to the natural dissolver system. In addition to the criticality concerns, such an addition would result in the production of NOx since scrap uranium is at a lower oxidation state than the natural uranium feed material. If such a scenario occurred, the NOx produced could exceed the ERPG-3 level for worker exposure. Unmitigated, this has the potential to be a high consequence event. Inadvertent addition of scrap material to the natural dissolver system is prevented by administrative controls on natural and enriched uranium materials, and by an enrichment monitor that is interlocked with the bridge crane to prevent the crane from moving a drum of enriched material, thus preventing its addition to the dissolver.

In addition to being a radiological hazard, uranium can also present a chemical toxicity hazard. Large spills of UO_3 powder during drum handling operations have the potential to result in an intermediate consequence event. To prevent such hazards, operators are trained in proper drum handling procedures. In addition, UO_3 drum handling for the natural dissolver process takes place in a hood to prevent inadvertent operator exposure.

<u>Scrap Uranium Dissolution:</u>

Chemicals in the scrap uranium dissolution process include:

- Uranyl Nitrate (UNH) product solution in dilute acidic solution (approximately 0.6 molar excess nitric acid).

<u>Chemical Reactions:</u>

The scrap uranium dissolution system dissolves scrap enriched uranium powder in nitric acid for recycle to the conversion process. To ensure the reaction is complete, excess acid added. The product is a UNH solution with 0.6 molar excess nitric acid. Scrap uranium compounds are normally not at the highest oxidation state. As a result, they normally produce NOx as an off gas in the dissolution reaction. The dissolution reactions are:

$$UO_2 + 4HNO_3 \rightarrow UO_2(NO_3)_2 + 2H_2O + 2NO_2 + \text{Heat}$$

and

$$U_3O_8 + 8HNO_3 \rightarrow 3UO_2(NO_3)_2 + 4H_2O + 2NO_2 + \text{Heat}$$

<u>Chemical Hazards:</u>

Chemical spills from the dissolver processes and process feed acid were analyzed. Spills of product solution and spills from the dissolver off gas scrubbing system did not meet the threshold for intermediate or high consequences for worker exposure. Spills were analyzed for all process equipment and the worst case with respect to potential personnel exposure was taken as the limiting case.

Spills and off gas leaks from the dissolver tanks Tk-76A and Tk-76B were analyzed for both acid fumes and NOx exposures. Worker exposure to acid fumes had the potential to exceed the ERPG-2 level for nitric acid. However, the

NOx fumes from the dissolution reaction had the potential to exceed the ERPG-3 level for worker exposure to NOx. Since both hazards are associated with process upsets in the dissolver A and B tanks, the NOx hazard is used as the limiting case. Unmitigated, this has the potential to be a high consequence event.

Process upsets that have the potential to release off gas to the room are prevented in several different ways. Integrity of the dissolver system and associated off gas system are ensured by using compatible materials of construction and by periodic inspections to ensure that equipment is properly maintained. In the event of process upsets that affect the dissolver off gas system, releases to the room are prevented by interlocks that shut down dissolver operations in the event of high vent header pressure, low dissolver scrubber differential pressure and low acid POG scrubber differential pressure. The dissolver off gas scrubber is also equipped with high and low differential pressure alarms to alert operators of upset conditions. Each process tank is equipped with a high temperature alarm to alert operators of any potential heater problems and prevent overheating and damage of vent system equipment. All tanks have high level alarms to alert operators of any upset conditions and prevent any backflow into the vent system. A high level interlock isolates dissolver feed flow preventing overflow from the system.

<u>Chemical Controls:</u>

<u>Natural Uranium Dissolver</u>

<u>Passive Engineered Controls</u>

- Natural uranium drum handling takes place in a hood

<u>Active Engineered Controls</u>

- Enrichment monitor interlocks bridge crane to prevent enriched material from being added to natural dissolver

<u>Administrative Controls</u>

- Operator procedures and training on segregation of enriched material from natural materials
- Operator procedures and training on proper drum handling

<u>Scrap Recovery Dissolver</u>

<u>Passive Engineered Controls</u>

- Compatible materials of construction
- Piping and vessels of welded construction

Active Engineered Controls

- High vent header pressure interlock
- Dissolver scrubber low differential pressure interlock
- Acid POG scrubber low differential pressure interlock
- High level in dissolver interlocks dissolver feed

Administrative Controls

- Periodic inspections to ensure system components are properly maintained
- Tank high level alarms on the Central Control System (CCS)
- Tank high temperature alarms on the CCS
- Scrubber high level alarm on CCS
- Scrubber high and low differential pressure alarm on CCS

Other provisions for managing the safe handling 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment. Process controls, alarm and interlocks, are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.5.2.3. Radiological Hazards and Controls (Dissolution)

The low enriched and the natural dissolution systems use engineered and administrative controls to ensure radiological safety. The primary radiological hazard for these systems 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.

There are three radiological materials in each dissolution system. One is a UN solution (Class D), the second is UO_2/U_3O_8 powder (Class Y), and the third is UO_3 powder (Class W). There are two dissolution systems and one contains natural uranium and the other uranium compounds that are enriched in the isotope U-235 and include the progeny of the isotopes of uranium as well as other radionuclides.

<u>Radiological Hazards:</u>

Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the three materials in either system did not meet the criteria for intermediate or high consequences to either worker or an individual located outside the control area. The releases evaluated included thermal stress, explosive release (i.e., pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

<u>Radiological Controls:</u>

<u>Passive Engineered Controls</u>

- Physical separation of natural and scrap dissolution components
- Dike containment

<u>Active Engineered Controls</u>

- HEPA filters
- Process Exhaust Ventilation Scrubber

<u>Administrative Controls</u>

- Personnel training and procedures
- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.5.2.4. Fire and Explosion Hazards and Controls (Dissolution)

<u>Fire Resulting from Heater Over-Temperature</u>

Heaters with low wattage are used to heat the natural uranium dissolver feed tank and the scrap dissolver tanks. Failure of a tank heater may result in an ignition source to local combustible material but is not expected to damage the metal tanks.

Fire Exposure to Process Equipment (Refer to Section 3.1.2.4)

Ventilation (Refer to Section 3.1.2.4)

Nitric Acid 20% and 60% Concentrations

Nitric Acid, at approximately 20% concentration, is used for dissolving natural uranium trioxide powder. Nitric Acid, at a 20% concentration, is identified as a Class 1 oxidizer per NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers.* A Class 1 oxidizer does not significantly increase the burning rate of combustible materials with which it comes into contact.

Nitric acid, at approximately 60% concentration, is used for dissolving scrap uranium dioxide powder in the first floor Conversion Area. Nitric acid, at a maximum 60% concentration, is categorized as a Class 2 oxidizer by NFPA 430A, *Storage of Liquid and Solid Oxidizing Materials.* The fire hazard for a Class 2 oxidizer is that it may cause a moderate increase in the burning rate of combustible material with which it comes into contact. In order to mitigate the fire hazard in the process areas, a combustible control program is to be implemented. Since transient combustibles are to be limited within the process areas where transient combustibles could come into contact with a release of nitric acid, the fire hazard analysis indicates that fire modeling is considered to bound a fire involving transient combustibles coming into contact with nitric acid at a maximum concentration of 60%.

Nitric Acid and Uranium Dioxide or Uranium Trioxide

Uranium dioxide and uranium trioxide are both noncombustible materials. Although introducing uranium dioxide or uranium trioxide to nitric acid at approximately 60 % and 20% concentrations will result in an exothermic reaction, flaming and smoldering of the uranium oxide or uranium trioxide is not expected.

Fire or Explosion Hazards:

- Fire Resulting from Heater Over-Temperature
- Fire Exposure to Process Equipment
- Nitric Acid 20% and 60% Concentration Contacting Combustible Materials
- Ventilation system

Fire or Explosion Controls:

Passive Engineered Controls

- Majority of process equipment constructed of noncombustible materials.
- Majority of ventilation system constructed from noncombustible materials.

- A 3-hour related fire barrier separating unsprinklered process area from remainder of facility.
- UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant
- Low wattage heaters for the natural uranium dissolver feed tank and the scrap dissolver tanks.

Active Engineered Controls

- Temperature monitoring of heaters.
- Automatic sprinkler system coverage in Tank Gallery and Natural Uranium Dissolver Room.
- Smoke detection interlocked to close the process hydrogen valve upon activation.

Administrative Controls

- Combustible control program.
- Hot work program.

3.5.2.5. Environmental Hazards and Controls – Public (Dissolution)

The environmental hazards for the OCB BLEU Uranium 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. For the Uranium Dissolution process, there are no chemical hazards that had the potential to exceed the above levels under postulated accident conditions. The environmental radiological hazards and controls for Uranium Dissolution are presented in Section 3.5.2.3.

The OCB building is designed to contain all process spills from the uranium dissolution process. Public exposure to process upsets in the uranium dissolution process is therefore limited to the exposure to exhaust fumes from the building that are generated by process upsets involving potentially hazardous materials. Potential public exposure due to a process upset was examined for each potentially hazardous chemical in the process. The potential exposure was taken to be the highest downwind concentration under the worst case atmospheric conditions. No cases examined had potential for intermediate or high consequence events due to public exposure.

Table 3-5
Hazard Summary for the Dissolution Processes

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• Backflow into unfavorable geometry utility or chemical makeup supplies • Overflow of tanks or piping/equipment leaks into unfavorable geometry containers, ventilation system or natural dissolution system • Direct addition of LEU to the natural dissolution system • Heat exchanger leakage into the unfavorable geometry cooling water supply system	• Passive overflows on vessels to favorable geometries (floor, catch pans, etc.) • Chemically resistant favorable geometry metal containers, columns, heat exchangers, and transfer pumps • Utility supply lines installed at higher elevation than overflow lines • Process off gas line elevation, above overflow lines prevents backflow to the process ventilation system • Process off gas line connections to the top of the process ventilation ductwork prevents potential backflow • Natural uranium powder is handled only in 55-gallon drums within the facility, whereas LEU powder is handled in dissimilar smaller containers constructed from 8-inch schedule 10 pipe • Natural uranium processing equipment is kept in an isolated room of the OCB building, separated from the LEU processes • Favorable geometry secondary cooling loop.	• Active interlocks on utility supplies to close supply valve when low pressure is sensed by pressure indicator transmitter • Active interlocks on cooling waterside of heat exchanger to shut down pumps when uranium-bearing solution is sensed by high conductivity monitor • Active interlocks on natural drum loading crane to prevent movement of drum if enriched material is detected • Active interlocks on natural UO3 powder feed enclosure to prevent transfer into the natural dissolver if 55-gallon drum is not detected by proximity switch	• Only favorable geometry containers allowed in LEU areas • Containers in the area must not be left open and unattended • Clear, easy to read markings and color-coding of containers based on enrichment within the OCB emphasizes the importance to keep LEU and natural uranium separate • Confirmation of shipper's data that 55-gallon drums contain only natural uranium powder

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Chemical Worker	• NOx and acid fumes from the scrap recovery dissolver off gas system	• Materials of construction • Natural uranium drum handling takes place in a hood	• Dissolver scrubber low differential pressure interlock shuts down system • Acid POG scrubber low differential pressure interlock shuts down system • High vent header pressure interlock shuts down system • Addition of enriched materials to natural dissolver prevented by enrichment monitor that interlocks bridge crane and prevents addition of enriched material • High level in dissolver interlocks dissolver feed	• Periodic Inspections • Operator response to tank dissolver tank high level alarms on the CCS • Operator response to tank dissolver tank high temperature alarms on the CCS • Operator response to dissolver scrubber high level alarms on the CCS • Operator response to dissolver scrubber high and low differential pressure alarms on the CCS • Addition of enriched materials to natural dissolver prevented by operator procedures and training on segregation of enriched and natural uranium materials • Operator procedures and training on proper drum handling
Radiological	• *Thermal stress* • Explosive release (i.e. pressurized venting effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• *Physical separation of natural and scrap dissolution components* • Dike containment	• HEPA filters • Process Exhaust Ventilation Scrubber	• Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Fire and Explosion	• Fire Resulting from Heater Over-Temperature • Fire Exposure to Process Equipment • Nitric Acid 10% Concentration Contacting Combustible Materials	• Majority of process equipment constructed of noncombustible materials. • Majority of ventilation system constructed from noncombustible materials. • Fire barrier separating unsprinklered process area from remainder of facility. • UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant • Low wattage heaters for the natural uranium dissolver feed tank and the scrap dissolver tanks	• Temperature monitoring of heaters. • Automatic sprinkler system coverage in Tank Gallery and Natural Uranium Dissolver Room. • Smoke detection interlocked to close the process hydrogen valve upon activation.	• Combustible control program. • Hot work program.
Environmental	• None	• None	• None	• None

3.6 VENTILATION PROCESS

3.6.1 Process Description

This section discusses the process equipment, which is ventilated, and the ventilation treatment methods used in the process ventilation systems.

Oxide Conversion Building

The process ventilation system includes equipment that collects, treats and discharges gaseous effluent from the process equipment and columns used in the oxide conversion process. The process ventilation system includes all the equipment installed between the processing enclosures/columns and the exhaust stack.

High Efficiency Particulate Airborne (HEPA) filters are used in the ventilation ductwork connected to hoods, scrubbers and maintenance (grinding and welding) areas. The HEPA filters are used to collect the entrained particulate, which may contain uranium. The HEPA filters help prevent the accumulation of an unsafe mass of uranium in the ductwork system over a period of time.

The HEPA filters are monitored with a differential pressure gauge that measures the pressure before and after the filter. Differential pressure is used to determine when a HEPA filter needs to be changed out with a new filter, or if the current filter is defective. If the differential pressure gauge indicates a filter needs changing, the filter is non-destructively analyzed (gamma scanned) and removed for proper disposal.

The process ventilation system ductwork connects the enclosures, scrubbers, and other process equipment to the main effluent stack. The layout of the ductwork is designed and installed to minimize the number of sections in which material can accumulate.

The ductwork varies in size throughout the ventilation system. The ductwork ranges in sizes from 2-inch diameter lines up to 10-inch from the process columns and enclosures. These ducts feed into progressively larger ducts, which eventually connect into a 26-inch line that feeds the final HEPA filter bank.

Several locations of the ductwork contain flanges and portals for the inspection and cleanout of the ductwork. The ductwork is gamma scanned periodically at identified locations to ensure no build-up of material occurs over time.

Process offgas lines (POG) are provided for all vessels that may contain acid or ammonia fumes. Vent lines are provided with low point drains and tie into the ventilation system at vertical ducts to provide protection against accumulation of an unsafe mass of uranium in the ventilation system. The vessels are equipped with separate overflow lines that drain to the floor to prevent any overflowing solution from entering the POG lines. In addition to the separate overflow lines, most vessels are equipped with high-high sensors which close off the inputs into the vessel if the liquid level reaches the sensor, preventing liquid overflow into the off gas system piping.

The acid and base process scrubber systems are used for the final treatment of the process ventilation effluent from a variety of sources including the calciner, dryer, columns, tanks, and other scrubbers. A dedicated scrubber is utilized in the dissolver system to remove NOx that is produced in the dissolution of scrap uranium powder. The scrubbed dissolver offgas is then sent to the acid POG system for final treatment. The scrubbed dissolver offgas and offgas from equipment containing acid solutions is scrubbed in the acid scrubber system. Off gas from the dryer and calciner are scrubbed in the base POG scrubber. The scrubbed off gas is discharged to the building ventilation exhaust system. Separate acid and base scrubbers are used to prevent the formation of ammonium nitrate in the scrubbers.

The ventilation offgas enters the scrubber near the bottom and is pulled up through the scrubber beds by a blower. As it is pulled through the scrubber, entrained particulate and effluent vapors are scrubbed with a scrubbing solution made up with deionized (DI) water.

The DI water enters the scrubber near the top, and flows down through the scrubber bed. The packed tower scrubbing bed allows the solution to flow through the scrubber in a manner that increases the efficiency of the scrubbing process. The water and scrubbed effluent are collected at the bottom of the scrubber and gravity drains into a condensate collection tank which transfers the solution to the Miscellaneous Uranium Storage Tank (TK-47B) for further processing.

After the process ventilation is pulled through the scrubbing bed, it is vented to the building ventilation system through a blower. The building ventilation is filtered through a HEPA filter and exhausted through the stack.

Effluent Processing Building

The liquid waste effluent from the ion exchange columns in the OCB is processed in the EPB. The feed stream contains only trace quantities of radionuclides, including uranium (typically in 1 ppm). A small capacity ventilation system is provided for containment of potential minor radionuclide releases from process equipment vents. The system includes equipment that collects, treats and discharges gaseous effluent from the process equipment in the Effluent Processing Building. The process ventilation system includes all the equipment installed between the processing equipment and the exhaust stack.

A High Efficiency Particulate Airborne (HEPA) filter is used in the process ventilation to collect the entrained particulate, which may contain uranium, from the process equipment.

The HEPA filter is monitored with a differential pressure gauge that measures the pressure before and after the filter. Differential pressure is used to determine when the HEPA filter needs to be changed out with a new filter, or if the current filter is defective.

Criticality safety in the EPB is mass controlled by maintaining the total inventory of fissile material in the facility to a subcritical mass. Individual pieces of process equipment do not have criticality safety limitations.

The Ammonia Recovery Process in the EPB is isolated from the rest of the facility due to the processing of high concentration ammonia solutions. Room exhaust from the Ammonia Recovery Process is combined with the process ventilation and discharged from the EPB stack.

Process Off-Gas Ventilation Lines

Process off-gas lines (POG) are provided for all tanks that may contain uranium and ammonia bearing solutions. The tanks in the EPB are equipped with separate overflow lines that drain to the floor to prevent any overflowing solution from entering the POG lines. In addition to the separate overflow lines, the tanks are equipped with High-High sensors which close off the inputs into a tank if the liquid level reaches the sensor.

Ammonia Recovery Scrubber

The ammonia recovery scrubber system is used for treatment of the process ventilation effluent from ammonia bearing equipment including the Ammonium Hydroxide storage tank.

The ventilation effluent enters the scrubber near the bottom and is pulled up through the packed bed by a blower. As it is pulled through the scrubber, ammonia vapors are absorbed with a countercurrent flow of DI water. The packed bed allows the scrubbing solution to flow through the scrubber in a manner that increases the efficiency of the scrubbing process. The water and scrubbed effluent are collected at the bottom of the scrubber and is returned to the ammonia recovery receipt tank.

After the process ventilation is pulled through the packed bed, it is vented to the building exhaust.

3.6.2 Hazard Identification and Controls (Ventilation)

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

3.6.2.1. Criticality Hazards and Controls (Ventilation)

The ventilation system incorporates passive and active engineered controls to ensure criticality safety, and compliance with the double contingency principle during operation of the system. The ventilation system consists of favorable geometry filtration and scrubber vessels, favorable and unfavorable geometry ducting and unfavorable geometry final effluent filtration.

The primary criticality safety hazards involve the migration and accumulation of uranium and moderator in unfavorable geometry ducting and final effluent filtration. Other criticality safety hazards involve the migration and accumulation of moderator in the ducting with backflow into unfavorable geometry processes relying on moderation control for criticality safety.

The safeguards to prevent the migration and accumulation of uranium in unfavorable geometry ducting include process off-gas filtration in favorable geometry vessels and ducting with additional HEPA filtration prior to entry into the unfavorable geometry portion of the ventilation system. Differential pressure gauges ensure that filters function as designed. Periodic NDA (gamma scan) surveillances confirm the lack of uranium accumulation in the favorable and unfavorable geometry ducting and filters.

Translucent condensate drains prevent an accumulation of moderation within the ventilation ducting. A condensate drain is provided on the ducting down stream of the scrubbers to accumulate and drain solution from the ducting. The process off-gas line is further directed to an open bottom, vertical section of ventilation ducting, which allows solution from an overflowing scrubber to drain directly to the floor.

To prevent the entry of moderator or condensate from the ventilation system to moderation-controlled equipment the ventilation ducting is elevated above the main line, which is further sloped to prevent moderator backflow. Condensate drains prevent the accumulation of moderator.

The safeguards for backflow of solution to the utilities include a passive overflow line for all process vessels to direct overflow upsets to favorable geometries and equipping the utility supplies with active engineered controls to isolate the system if pressure is lost.

Criticality Hazards:

- Migration and accumulation of uranium and/or moderator in unfavorable geometries.
- Solution backflow into unfavorable geometry utility or chemical makeup supplies.

Criticality Controls:

Passive Engineered Controls

- Passive overflows on vessels and ventilation condensate drains to favorable geometries (floor, catch pans, etc.).

- Chemically resistant favorable geometry metal containers, columns, and transfer pumps.

- Passive off-gas filtration with additional HEPA filtration prior to entry into unfavorable geometry ventilation ducting.

- Moderation controlled area ventilation input elevation above the main line and further sloped to facilitate migration to the condensate drains.

Active Engineered Controls

- Active interlocks on utility supplies to close supply valve when pressure indicator transmitter senses low supply pressure.

Administrative Controls

- Periodic NDA (gamma scan) of the process ventilation ducting to detect and remove accumulations.

3.6.2.2. Chemical Hazards and Controls – Worker (Ventilation)

Chemicals in the ventilation process include:

- Ammonia in process off gases and in process solutions containing ammonium hydroxide

- Hydrogen in process off gases

- Nitrogen in process off gases

- Ammonium nitrate

Chemical Reactions:

Separate scrubbers are used to prevent the formation of ammonium nitrate in the gas stream. The bottoms liquid from the acid scrubber contains a small amount of nitric acid and the bottoms liquid from the base scrubber contains a small amount of ammonium hydroxide. These two solutions are mixed in the condensate tank, resulting in the formation of ammonium nitrate. The amount of ammonia in the off gas is greater than the amount of acid, so the solution will have excess ammonia. The result is a basic solution of dilute ammonium nitrate. Ammonium nitrate is formed by the reaction:

$HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$

Chemical Hazards:

The chemical hazards associated with the ventilation system are the result of chemicals in the off gas from the various units connected to the vent system. These chemicals include ammonia and hydrogen in the off gas from the dryer and calciner, and acid fumes from various acid tanks and the scrap dissolver scrubber exhaust gas.

The potential effects of off gas leaks were examined. Releases of acid fumes from the acid POG scrubbing system and releases of ammonia fumes from the base tank vent header did not meet the threshold for intermediate or high consequences for worker exposure.

In the base off gas scrubber, sufficient ammonia is present in the off gas to exceed the ERPG-2 level for ammonia to the worker in the event of a complete off gas leak to the room. Unmitigated, this has the potential to result in intermediate consequences. In addition, hydrogen is present in the base system off gas. Due to the potential fire hazard associated with hydrogen, it was assumed that a major base POG off gas leak to the room would result in a fire. A fire in the room where the calciner is located was examined and determined to have the potential for high consequences to the worker. The high consequence case was taken to be bounding, so a leak in the calciner off gas was considered to have the potential for high consequence to the worker.

Protection against off gas leaks is provided by the integrity of the system boundaries. This is done by ensuring that compatible materials of construction are used for the materials handled. Periodic equipment inspections ensure that the systems are properly maintained.

Prior to discharging the base process off gas into the main ventilation system, the hydrogen is in an inert atmosphere. At the point of addition to the ventilation system, the building ventilation system is sufficient to reduce the hydrogen concentration to below the LEL, thus eliminating potential fire risks. Hydrogen is maintained below the LEL in the ventilation ducting by interlocks that sense hydrogen concentration and dilution air flow. If hydrogen concentration becomes too high, or if dilution air flow is too low, the hydrogen supply valve is shut to prevent the buildup of an explosive mixture.

The off gas ventilation system is operated at slight vacuum conditions. For this reason, small leaks would be more likely to allow air into the off gas piping than to allow off gas to escape. This could potentially introduce oxygen into the inert portion of the off gas piping. The primary defense against this is the use of proper materials of construction in the off gas piping to prevent leaks. In addition, an oxygen sensor detects inleakage of oxygen and isolates the hydrogen supply to prevent an explosive mixture of hydrogen and oxygen in the off gas.

Ammonium nitrate is present in the process due to the mingling of the acid and base scrubber bottoms liquids. Since it is not possible to predict the exact nature of damage to a potential detonation of ammonium nitrate, the occupational consequences were conservatively considered to be high.

The condensate tank contains approximately 2% ammonium nitrate by weight. Detonation is not considered to be a risk as long as the concentration of ammonium nitrate remains below 92% according to the Fire Protection Handbook. Even though the process solution is far below this concentration, the possibility exists that, due to operator error a pump could be run dead-headed for a sufficient period of time to allow heat to build up and water to boil off until a critical concentration was reached. This is a slow process that would require many hours to transpire. In order to prevent this remote possibility, pumps have recirculation lines that circulate a portion of the solution back to the source tank to remove heat and prevent drying out of the pump. In addition, temperature alarms are provided to alert the operator well before the pump casing temperature climbs to the point where a critical concentration of ammonium nitrate could detonate.

Condensate solution contains excess ammonium hydroxide. A Spill of condensate solution has the potential to exceed the ERPG-3 level for worker ammonia exposure. Unmitigated, this has the potential to be a high consequence event. Leaks and ruptures are prevented by ensuring that the equipment is designed with compatible materials of construction and by period inspection to ensure equipment is properly maintained. Tank overflow situations are prevented by operator response to tank high level alarms and high level interlocks that shut down process feed flow in the event of a high level. A spill due to inadvertent draining of the condensate tank is prevented by operator training. In addition, the drain line is plugged to prevent inadvertent discharge of liquid to the room.

<u>Chemical Controls:</u>

<u>Passive Engineered Controls</u>

- Compatible materials of construction
- Condensate pump recirculation piping
- Condensate tank drain line plugged

<u>Active Engineered Controls</u>

- Low air flow in the ventilation system interlocks to isolate the hydrogen supply
- High hydrogen concentration in the air stream interlocks to isolate the hydrogen supply
- Oxygen sensor shuts off hydrogen supply if high levels of oxygen are detected in scrubber off gas piping
- Condensate tank high level interlock isolates feed flow

<u>Administrative Controls</u>

- Periodic Equipment Inspection

- Operator response to condensate pump casing high temperature alarm
- Operator response to condensate tank high level alarm
- Operator training and procedures to prevent inadvertent condensate tank draining

Other provisions for managing the safe handling 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment and process controls, alarm and interlocks, are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.6.2.3. Radiological Hazards and Controls (Ventilation)

The ventilation system uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the ventilation is transport of radiological material to the environment due to a loss of containment. Containment is maintained by materials of construction and verified by the radiological monitoring program.

There are four radiological materials associated with the ventilation system. They are UN solution (Class D), ADU solution/slurry (Class W), UO_2/U_3O_8 powder (Class Y), and UO_3 powder (Class W). These uranium compounds can be either natural (UN solution and UO_3 powder) or enriched in the isotope U-235 and may include the progeny of the isotopes of uranium as well as other radionuclides.

<u>Radiological Hazards:</u>

Loss of containment and subsequent potential airborne release of the radiological materials though the ventilation system were analyzed. Explosion scenarios 1 through 4 identified in the FHA were assumed as high consequence events to both the worker and an individual located outside the control area based on the inherent severity of the event(s). The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

Passive Engineered Controls

- Closed ventilation system

Active Engineered Controls

- Oxygen analyzer downstream of off-gas scrubber
- High/low pressure interlocked with Hydrogen supply valves
- Hydrogen-air dilution blower
- Hydrogen gas detector downstream of air-dilution system
- HEPA filters
- Process Exhaust Ventilation Scrubber

Administrative Controls

- Personnel training and procedures
- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.6.2.4. Fire and Explosion Hazards and Controls (Ventilation)

<u>HEPA Filter Fire Exposure</u>

Flanders Filter, Inc. indicated that the type of HEPA filter units used on the Oxide Conversion Building has a maximum thermal operating temperature of 250°F. The HEPA filters meet the criteria of UL 900, Class 1, with frames constructed from wood, treated with a fire retardant. Fire damage to the HEPA filters may occur if a transient combustible fire is within 4 feet of the HEPA filter unit. HEPA filter media may also be damaged if sparks or embers from a fire at a process hood are drawn into the ventilation system and contact the HEPA filter media and any combustible material collected on the filters. Assuming the HEPA filter unit at 50% of the maximum temperature for the upper thermal layer in the Conversion Area, no thermal damage effects are expected to this HEPA filter unit from the expected upper thermal layer temperatures. In addition, the fork truck propane torch fire will not damage the HEPA filter unit as long as a minimum 12 feet of separation is maintained between the fork truck and the filter unit.

Assuming the HEPA filter will only see the lower thermal layer of a bounding fire scenario based on the height of the ceiling and the location of the HEPA filter, no thermal damage effects are expected to this HEPA filter unit from the expected lower thermal layer temperatures.

<u>Fire or Explosion Hazards:</u>

- HEPA Filter Fire Exposure

<u>Fire or Explosion Controls:</u>

<u>*Passive Engineering Controls*</u>

- UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant

<u>*Administrative Controls*</u>

- Combustible control program.
- Hot work program.

3.6.2.5. Environmental Hazards and Controls – Public (Ventilation)

The environmental hazards for the OCB BLEU Ventilation 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. For the Ventilation process the following chemical hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions. The environmental radiological hazards and controls for ventilation are presented in Section 3.6.2.3.

The building is designed to contain all process spills from the ventilation scrubber processes. Public exposure to process upsets in the ventilation system is therefore limited to the exposure to exhaust fumes from the building that are generated by process upsets involving potentially hazardous materials.

Potential public exposure due to a process upset was examined for each potentially hazardous chemical in the process. The potential exposure was taken to be the highest downwind concentration under the worst case atmospheric conditions. Only two cases examined had potential for intermediate or high consequence events due to public exposure. The first case was a fire caused by a hydrogen leak in the base off gas scrubbing system. The potential toxic fume release that could be associated with such a fire had the potential to exceed the ERPG-1 level for public exposure. Unmitigated, this has the potential to be an intermediate consequence event. The second case was in the event of an ammonium nitrate detonation. Since it is not possible to predict the exact nature of damage to a potential detonation, the environmental consequences were conservatively considered to be high. A detailed discussion of the postulated hazard scenarios and associated safeguards is given in Section 3.6.2.2

Table 3-6
Hazard Summary for the OCB Ventilation

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• Migration and accumulation of uranium and/or moderator in unfavorable geometries • Solution backflow into unfavorable geometry utility or chemical makeup supplies	• Passive overflows on vessels and ventilation condensate drains to favorable geometries (floor, catch pans, etc.) • Chemically resistant favorable geometry metal containers, columns, and transfer pumps • Utility supply lines are elevated above the scrubber input and off-gas ventilation lines • Passive off-gas filtration with additional HEPA filtration prior to entry into unfavorable geometry ventilation ducting • Moderation controlled area ventilation input elevation above the main line and further sloped to facilitate migration to the condensate drains	• Active interlocks on utility supplies to close supply valve when pressure indicator transmitter senses low supply pressure	• Periodic NDA (gamma scan) of the process ventilation ducting to detect and remove accumulations
Chemical Worker	• Ammonia fumes from off gas piping or condensate solution spills • Ignition of hydrogen in off gas • Ammonium nitrate explosion	• Materials of construction • Condensate pump recirculation piping • Condensate tank drain line plugged	• Low air flow interlocks shut off hydrogen supply • High hydrogen concentration interlocks shut off hydrogen supply • High oxygen concentration in scrubber interlocks shut off hydrogen supply • Condensate tank high level interlocks shut off feed flow	• Periodic equipment inspections • Operator response to condensate pump casing high temperature alarm • Operator response to condensate tank high level alarm • Operator training and procedures to prevent inadvertent condensate tank draining

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Radiological	• Thermal stress • Explosive release (i.e. pressurized venting effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• Closed ventilation system	• HEPA filters • Process Exhaust Ventilation Scrubber • Oxygen analyzer downstream of off-gas scrubber • High/low pressure interlocked with hydrogen supply valves • Hydrogen-air dilution blower • Hydrogen gas detector downstream of air-dilution system	• Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)
Fire and Explosion	• HEPA Filter Fire Exposure	• Majority of ventilation system constructed from noncombustible materials. • UL 900, Class 1 HEPA filters with frames constructed form wood treated with a fire retardant.	• None	• Combustible control program. • Hot work program.
Chemical Environmental	• Toxic fumes from fire in the event of ignition of hydrogen in off gas • Ammonium nitrate explosion resulting in damage that causes off site release of toxic gas	• Materials of construction • Condensate pump recirculation piping	• Low air flow interlocks shut off hydrogen supply • High hydrogen concentration interlocks shut off hydrogen supply • High oxygen concentration in scrubber interlocks shut off hydrogen supply	• Periodic inspections • Maintenance procedures and training • Operator response to condensate pump casing high temperature alarm

3.7 AMMONIA RECOVERY PROCESS

3.7.1 <u>Process Description</u>

3.7.2 <u>Hazard Identification and Controls (Ammonia Recovery)</u>

A summary table of hazards and controls for Ammonia Recovery is included as Table 3-7.

3.7.2.1. Criticality Hazards and Controls (Ammonia Recovery)

The ammonia recovery/liquid waste system incorporates robust active engineered and administrative controls to ensure criticality safety, and compliance with the double contingency principle during operation of the system. The ammonia recovery/liquid waste operation is performed in unfavorable geometry vessels under very robust mass controls.

The only external feed to the ammonia recovery/liquid waste system (EPB) is effluent from the OCB Ion Exchange (IX) columns. During normal operation, the effluent uranium concentration is approximately 1-ppm. The primary criticality safety hazards for the EPB involve discharge to or accumulation of sufficient uranium mass. Initiating events, such as valve misalignment, valve failure, pH control failure in the ion exchange system, process flow control failure in the ion exchange system, ion exchange resin failure, or cross flow filter failure would have to occur to create a pathway from the OCB Uranium Recovery process to the EPB. Dual independent uranium analyzers interlocked to multiple independent valves prevent the transfer of a sufficient uranium mass to the EPB. Conical bottom effluent tanks [redacted]allons) with recirculation capability, routine uranium sampling and tank surveillances further prevent a sufficient uranium mass accumulation within the EPB.

<u>**Criticality Hazards:**</u>

- Sufficient uranium mass discharge to or accumulation within the unfavorable geometry EPB process equipment.

<u>**Criticality Controls:**</u>

<u>*Passive Engineered Controls*</u>

- Conical bottom effluent tanks [redacted]gallons) prevent uranium accumulations

<u>*Active Engineered Controls*</u>

- Uranium analyzer, independent controller, interlocks, three-way valve, and block and bleed valve arrangement to limit the IX effluent from the OCB.

- Redundant uranium analyzer, independent controller, interlocks, three-way valve, and block and bleed valve arrangement to limit the IX effluent from the OCB.

<u>*Administrative Controls*</u>

- A mass balance is performed for the EPB to detect uranium hold-up.

- Annual tank inspection (more frequent inspection if warranted based on laboratory analysis) to prevent sufficient uranium mass accumulation in the EPB.

- Periodic NDA (gamma scans) of EPB equipment not directly accessible.

3.7.2.2. Chemical Hazards and Controls – Worker (Ammonia Recovery)

Chemicals in the ammonia recovery process include:

- Process effluent liquid containing dilute ammonium hydroxide.
- Ammonium nitrate in dilute aqueous solution (approximately 10% by weight).
- Sodium hydroxide solution at approximately 50% strength
- Aqueous ammonia solution (approximately 23% weight ammonia) from the stripper column overhead stream
- Sodium nitrate solution in the stripper column bottoms stream

Chemical Reactions:

Ammonia is recovered from the process effluent liquid by steam stripping. In order to ensure all the ammonia from the ammonium nitrate is recovered, sodium hydroxide is added which reacts with the ammonium nitrate to liberate the ammonia for recovery. The reaction is:

$NaOH + NH_4NO_3 \rightarrow NH_4OH + NaNO_3$

The NaOH is added in excess to ensure complete reaction and to control pH so that effective ammonia recovery can be performed in the stripper.

Chemical Hazards:

Spills or leaks of effluent solutions from tanks Tk-50 and Tk-51 have the potential to exceed the ERPG-2 level for ammonia exposure. Unmitigated, this has the potential to be an intermediate consequence event. Leaks and ruptures are prevented by ensuring that the equipment is designed with compatible materials of construction and by periodic inspection to ensure equipment is properly maintained. In the case of tanks, overflow situations that have the potential for intermediate consequences due to worker exposure to ammonia fumes are prevented by operator response to tank high level alarms and high level interlocks that shut down process feed flow in the event of a high level. In the case of tank 51, protection from backflow from the scrubber column is also provided by shutting the column supply valve in the event of loss of pumping capability from P-51. Overpressurization of tank Tk-50 and Tk-51 is prevented by having overflow/vent lines on each tank.

It is assumed that inadvertent venting of ammonia fumes from process equipment due to overpressure of the ammonium hydroxide tank or the distillate tank could result in high chemical consequences. To prevent this, process tanks are vented to atmosphere through the process off gas scrubber and equipped with a high pressure alarm. Process upsets such as loss of scrubber bottoms flow due to blocking in the bottoms line or loss of scrubbing liquid flow to the process off gas scrubber have the potential to allow unscrubbed off gas to discharge to the environment. A low scrubbing water flow alarm and high ammonia concentration alarms alert the operator to loss of scrubbing liquid flow and procedures, training and tamper seals prevent improper valve operation that could result in a high consequence ammonia release due to a loss of scrubber bottoms flow.

Due to the high temperatures involved in steam stripping and the strength of the recovered aqueous ammonia solution, spills or leaks would have a very high vapor pressure for ammonia and thus be expected to have strong ammonia fumes associated with them. Due to the process conditions, the size of the building and the short distance to the site boundary, spills or leaks of solutions from the ammonia recovery column, overhead condenser, distillate tank or other associate equipment were assumed to have the potential for high consequences to workers and the public without calculation. Ammonia recovery system integrity is maintained by ensuring that proper materials of construction are used, that all welded construction is utilized and by periodic inspection to ensure that system components are properly maintained. Overpressure conditions that have the potential to cause leaks or ruptures are prevented by a high pressure interlock that shuts down the steam supply to the column and by operator response to the column high pressure alarm on the Central Control System.

Ammonium nitrate is present in the liquid effluent feed to the process. Since it is not possible to predict the exact nature of damage to a potential detonation of ammonium nitrate, the occupational consequences were conservatively considered to be high.

The OCB process effluent contains approximately 10% ammonium nitrate by weight. Detonation is not considered to be a risk as long as the concentration of ammonium nitrate remains below 92% according to the Fire Protection Handbook. Even though the process solution is far below this concentration, the possibility exists that, due to operator error, a pump could be run dead-headed for a sufficient period of time to allow heat to build up and water to boil off until a critical concentration was reached. This is a slow process that would require many hours to transpire. In order to prevent this remote possibility, pumps have recirculation lines that circulate a portion of the solution back to the source tank to remove heat and prevent drying out of the pump. In addition, temperature alarms are provided to alert the operator well before the pump casing temperature climbs to the point where a critical concentration of ammonium nitrate could detonate.

<u>**Chemical Controls:**</u>

Passive Engineered Controls

- Compatible materials of construction
- Piping and vessels of welded construction
- Pump recirculation lines
- Tk-50 overflow/vent line

- Tk-51 overflow/vent line
- Process tanks vented through scrubber

Active Engineered Controls

- Tank high level interlocks to shut off feed flow
- Ammonia recovery column high pressure interlock removes the system pressure source by isolating the steam supply to the ammonia recovery column
- Column feed valve interlocks closed on loss of column feed pump

Administrative Controls

- Periodic inspections to ensure system components are properly maintained
- Tank high level alarms on the Central Control System (CCS)
- Pump casing high temperature alarms
- Ammonia recovery column high pressure alarm on the CCS
- Tank High Pressure alarms on CCS
- High Discharge Ammonia Concentration alarm on CCS
- Low scrubber liquid flow alarm on CCS
- Tamper seals
- Operator training and procedures

Other provisions for managing the safe handling 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment, and process controls, alarms and interlocks are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.7.2.3. Radiological Hazards and Controls – Worker (Ammonia Recovery)

The ammonia recovery process uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the ammonia recovery 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.

The one radiological material of concern of ammonia recovery is ADU solution (Class W). This solution has trace amounts of uranium (approximately 1ppm) that is enriched in the isotope U-235 and includes the progeny of the isotopes of uranium as well as other radionuclides.

Radiological Hazards:

Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the ADU solution did not meet the criteria for intermediate or high consequences to a worker or an individual located outside the control area. The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

Passive Engineered Controls

- Physical separation of ammonia recovery components
- Dike containment

Active Engineered Controls

- HEPA filters
- Process Exhaust Ventilation Scrubber

Administrative Controls

- Personnel training and procedures
- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.7.2.4. Fire and Explosion Hazards and Controls (Ammonia Recovery)

Ammonia Fire or Explosion

Ammonia is to be recovered from the liquid waste stream from the Oxide Conversion Building. The solution is fed to a stainless steel distillation tower that uses steam to separate out reusable ammonia from the oxide conversion process effluent. The column is normally operated at 250°F and 30 psig. Anhydrous ammonia has an ignition temperature of 1204 °F with an explosive limit range of 16 to 25 percent by volume. Due to the potential of an ammonia vapor release that may present health hazards, the ammonia recovery tank, ammonia stripper column, ammonia condenser, hydroxide distillate tank, and the ammonia process off-gas scrubber are located in an area partitioned from the remainder of the building. The top portion of the ammonia stripper column where the potential exists for an ammonia release that may exceed the lower explosion limit of ammonia are enclosed within a room. Since ammonia vapor under abnormal operating conditions may be above its LEL in the room enclosing the top portion of the ammonia stripper column, the fire hazard analysis recommends that electrical within this area be Class 1, Division 2, Group D. It has also been recommended for building ventilation and process ventilation conveying vapors and gases to be installed in accordance with NFPA 91. This includes fan units constructed in accordance with Sections 4-2, 4-3, 4-4, and 4-5 for the ventilation system from the Ammonia Recovery Area.

An ammonia detection system is provided in the ammonia recovery area set to alarm to warn occupants that ammonia concentrations in the area presents a health hazard. The ammonia detection system provides a local alarm in the Effluent Process Area. Since the concentration where ammonia presents a health hazard is significantly less than the LEL for ammonia, personnel would be expected to respond to the alarm prior to the ammonia vapor concentration reaching its LEL in the ammonia recovery area and mitigate the ammonia vapor release. A fire or explosion involving ammonia is considered highly unlikely if ignition sources and ammonia vapors are controlled in the area by providing Class 1, Division 2, Group D electrical, providing a building area ventilation system that complies with NFPA 91, controlling combustible loading within the Effluent Process Building (including prohibiting storage of the plastic waste storage bags in the building), and utilizing tanks that provide a flame spread rating of less than 30 based on ASTM E84 test criteria for the [redacted] gallon tanks to minimize the potential fire exposure to the ammonia stripper column. Automatic sprinkler protection also is provided for the Ammonia Recovery Area.

Fire or Explosion Hazards:

- Ammonia Fire or Explosion

Fire or Explosion Controls:

Passive Engineered Controls

- Majority of process equipment within the Ammonia Recovery Area constructed of noncombustible materials.
- Majority of ventilation system constructed from noncombustible materials.
- Constructing the two [redacted]gallon fiberglass reinforced plastic tanks from a resin that provides a flame spread rating of less than 30 based on ASTM E84 test criteria.
- Class 1, Division 2, Group D electrical in room enclosing top portion the ammonia stripper column.
- Ventilation and process ventilation conveying vapors and gases designed and installed in accordance with NFPA 91.
- UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant

Active Engineered Controls

- Automatic sprinkler system coverage throughout areas within the Effluent Process Building.
- Ammonia detection system.

Administrative Controls

- Combustible control program.
- Hot work program.
- Prohibiting the storage of the plastic waste storage bags in the Effluent Process Building.

3.7.2.5. Environmental Hazards and Controls – Public (Ammonia Recovery)

The environmental hazards for the BLEU Ammonia Recovery 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. For the Ammonia Recovery Process the following chemical hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions. The environmental radiological hazards and controls for Ammonia Recovery are presented in Section 3.7.2.3.

The Effluent Processing Building (EPB) is designed to contain all process spills from the ammonia recovery process process. Public exposure to process upsets in the uranium precipitation process is therefore limited to the exposure to exhaust fumes from the building that are generated by process upsets involving potentially hazardous materials.

Potential public exposure due to a process upset was examined for each potentially hazardous chemical in the process. The potential exposure was taken to be the highest downwind concentration under the worst case atmospheric conditions. Due to the processing conditions associated with a potential spill or leak from the ammonia recovery process and the unknown extent of damage that could result from an ammonium nitrate explosion, the public consequences for each of these scenarios was conservatively assumed to be high without calculations. A detailed discussion of the postulated hazard scenarios and associated safeguards is given in section 3.7.2.2.

Table 3-7
Hazard Summary for the Ammonia Recovery/Liquid Waste Processes

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• Sufficient uranium mass discharged to or accumulated within the unfavorable geometry EPB process equipment	• Conical bottom effluent tanks (5,000-gallons) prevent uranium accumulation.	• Uranium analyzer, independent controller, interlocks, three-way valve, and block and bleed valve arrangement to limit the IX effluent from the OCB. • Redundant uranium analyzer, independent controller, interlocks, three-way valve, and block and bleed valve arrangement to limit the IX effluent from the OCB.	• A mass balance is performed on a weekly composite sample to determine the amount of uranium entering the EPB for the EPB to detect uranium hold-up. • Annual tank inspection (more frequent inspection if warranted based on laboratory analysis) to prevent sufficient uranium mass accumulation in the EPB. • Periodic NDA gamma scans of EPB equipment not directly accessible.
Chemical Worker	• Exposure to ammonia fumes from spills or leaks from the system.	• Materials of construction • Piping and vessels of welded construction • Pump recirculation lines • Tk-50 overflow/vent line • Tk-51 overflow/vent line • Process tanks vented through scrubber	• Tank high level interlocks isolate feed flow • Ammonia recovery column high pressure interlock isolates column steam supply • Column feed valve interlocks closed on loss of column feed pump	• Periodic equipment inspections • Operator response to tank high level alarm • Operator response to ammonia recovery column high pressure alarm • Operator response to pump casing high temperature alarm • Tank High Pressure alarms on CCS • High Discharge Ammonia Concentration alarm on CCS • Low scrubber liquid flow alarm on CCS • Tamper seals • Operator training and procedures

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Radiological	• Thermal stress • Explosive release (i.e. pressurized venting effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• Physical separation of ammonia recovery components • Dike containment	• HEPA filters • Process Exhaust Ventilation Scrubber	• Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)
Fire and Explosion	• Ammonia Fire or Explosion	• Majority of process equipment within the Ammonia Recovery Area constructed of noncombustible materials. • Majority of ventilation system constructed from noncombustible materials. • Constructing the two [redacted]allon fiberglass reinforced plastic tanks from a resin that provides a flame spread rating of less than 30 based on ASTM E84 test criteria. • Class 1, Division 2, Group D electrical in room enclosing top portion the ammonia stripper column. • Ventilation and process ventilation conveying vapors and gases designed and installed in accordance with NFPA 91. • UL 900, Class 1 HEPA filters with frames constructed from wood treated with a fire retardant	• Automatic sprinkler system coverage throughout areas within the Effluent Process Building. • Ammonia detection system.	• Combustible control program. • Hot work program. • Prohibiting the storage of the plastic waste storage bags in the Effluent Process Building.

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Environmental	• Exposure to ammonia fumes from spills or leaks from the system.	• Materials of construction • Piping and vessels of welded construction • Pump recirculation lines • Process tanks vented through scrubber	• Tank high level interlocks isolate feed flow • Ammonia recovery column high pressure interlock isolates column steam supply	• Periodic equipment inspections • Operator response to tank high level alarm • Operator response to ammonia recovery column high pressure alarm • Operator response to pump casing high temperature alarm • Tank High Pressure alarms on CCS • High Discharge Ammonia Concentration alarm on CCS • Low scrubber liquid flow alarm on CCS • Tamper seals • Operator training and procedures

3.8 LIQUID WASTE PROCESS

3.8.1 Process Description

3.8.2 Hazard Identification and Controls (Liquid Waste)

A summary table of hazards and controls for Liquid Waste is included as Table 3-8.

3.8.2.1. Criticality Hazards and Controls (Liquid Waste)

Criticality hazards and controls for the Liquid Waste process are included in the Ammonia Recovery Process Section 3.7.2.1.

3.8.2.2. Chemical Hazards and Controls – Worker (Liquid Waste)

Chemicals in the liquid waste process include:

- Process effluent liquid containing sodium nitrate in basic solution
- Dilute nitric acid (approximately 10% by weight)

Chemical Reactions:

The liquid waste system takes the bottoms stream of sodium nitrate solution and concentrates it in an evaporator. The liquid waste is then stabilized in concrete and cured in preparation for shipment. Besides adjustment of bottoms stream pH, there are no bulk phase chemical reactions in the process.

Chemical Hazards:

Chemical spills of all process solutions were analyzed. The spill scenarios associated with the liquid waste handling system did not meet the threshold for intermediate or high consequences for worker exposure. Spills were analyzed for all process equipment and the worst case with respect to potential personnel exposure was taken as the limiting case.

Chemical Controls:

General provisions are in place for managing the safe handling and use of hazardous chemicals which are integrated into the processing of radioactive materials or are generated by chemical reaction during processing of radioactive materials. These provisions 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment, and process controls, alarms and interlocks are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.8.2.3. Radiological Hazards and Controls – Worker (Liquid Waste)

The liquid waste system uses engineered and administrative controls to ensure radiological safety. The primary radiological hazard for the 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.

The one radiological material of concern of the liquid waste system is a sodium nitrate solution (Class W) that contains trace quantities of uranium (approximately 1ppm). The uranium in the solution is enriched in the isotope U-235 and the solution includes the progeny of the isotopes of uranium as well as other radionuclides.

Radiological Hazards:

Loss of containment and subsequent potential airborne release of the radiological material were analyzed. Release of the ADU solution did not meet the criteria for intermediate or high consequences to a worker or an individual located outside the control area. The releases evaluated included thermal stress, explosive release (i.e. pressurized venting effects), free-fall spills, and aerodynamic entrainment and resuspension.

Radiological Controls:

Passive Engineered Controls

- Physical separation of liquid waste components
- Dike containment

Active Engineered Controls

- HEPA filters
- Process Exhaust Ventilation Scrubber

Administrative Controls

- Personnel training and procedures
- Radiation protection program controls
- Radiation Protection Program monitoring and instruments (enhanced)

3.8.2.4. Fire and Explosion Hazards and Controls (Liquid Waste)

Polypropylene Waste Storage Bags

The evaporator concentrate bottoms is mixed with clay and cement and discharged into plastic waste storage bags for curing. Each polypropylene waste storage bag weighs approximately 33 pounds. During the curing cycle the plastic waste storage bags and contents will be contained in a metal container. To mitigate the fuel loading and potential fire exposure to the fiberglass reinforced plastic storage tanks in the Effluent Process Building from the polypropylene waste storage bags, the plastic waste storage bags are not to be stored within the building.

Fiberglass Reinforced Plastic Storage Tanks

Two [redacted]gallon and two [redacted]gallon tanks constructed of fiberglass reinforced plastic in accordance with ASTM 3299 "Specification for Filament Wound Glass Fiber Reinforced Thermoset Resin Corrosion Resistant Tanks."

In order to reduce the potential fire risk from the fiberglass reinforced plastic tanks and potential fire exposure to the ammonia stripper column, the two [redacted] gallon fiberglass reinforced plastic tanks in the Effluent Process Building are constructed of a resin that provides a flame spread rating of less than 30 based on ASTM E84 test criteria. The two [redacted]allon fiberglass reinforced plastic tanks contain water.

Sodium Nitrate

The liquid bottoms from the ammonia stripper column contain approximately 70 g/liter of sodium nitrate and the evaporator concentrate (bottoms) contain approximately 400 g/liter of sodium nitrate. Sodium nitrate is an oxidizer that promotes combustion of other materials. In order to mitigate the potential for sodium nitrate contacting transient combustible materials in the process areas, a combustible control program will be implemented.

Fire or Explosion Hazards:

- Polypropylene Waste Storage Bags
- Fiberglass Reinforced Plastic Storage Tanks
- Sodium Nitrate

Fire or Explosion Controls:

Passive Engineered Controls

- With exception of the four fiberglass reinforced plastic storage tanks, the majority of process equipment is constructed of noncombustible materials.
- Majority of ventilation system constructed from noncombustible materials.
- Construct the two [redacted]gallon fiberglass reinforced plastic tanks from a resin that provides a flame spread rating of less than 30 based on ASTM E84 test criteria.

Active Engineered Controls

- Automatic sprinkler system coverage throughout areas within the Effluent Process Building.

Administrative Controls

- Combustible control program.
- Hot work program.
- Prohibiting the storage of the plastic waste storage bags in the Effluent Process Building.

3.8.2.5. Environmental Hazards and Controls – Public (Liquid Waste)

The environmental hazards for the BLEU Liquid Waste Processing 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. For Liquid Waste Processing the following chemical hazards were evaluated to determine if they had the potential to exceed the above levels under postulated accident conditions. The environmental radiological hazards and controls are presented in Section 3.8.2.3.

The Effluent Processing Building is designed to contain spills from the liquid waste process. Public exposure to process upsets in the liquid waste process is therefore limited to the exposure to exhaust fumes from the building that are generated by process upsets involving potentially hazardous materials.

Potential public exposure due to a process upset was examined for each potentially hazardous chemical in the process. The potential exposure was taken to be the highest downwind concentration under the worst case atmospheric conditions. No cases were found that had potential for intermediate or high consequence events due to public exposure. General provisions and safeguards for use and handling of potentially hazardous chemicals to minimize the potential for any public exposure are discussed in Section 3.8.2.2

Table 3-8
Hazard Summary for the Liquid Waste Processes

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• See Table3.7	• See Table 3.7	• See Table 3.7	• See Table 3.7.
Chemical Worker	• No chemical hazards with potential for intermediate or high consequences identified	• None	• None	• None
Radiological	• Thermal stress • Explosive release (i.e. pressurized venting effects) • Free-fall spills • Aerodynamic entrainment and resuspension	• Physical separation of liquid waste components • Dike containment	• HEPA filters • Process Exhaust Ventilation Scrubber	• Personnel training and procedures • Radiation Protection Program controls • Radiation Protection Program monitoring and instruments (enhanced)

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Fire and Explosion	• Polypropylene Waste Storage Bags • Fiberglass Reinforced Plastic Storage Tanks • Sodium Nitrate	• With exception of the four fiberglass reinforced plastic storage tanks, the majority of process equipment is constructed of noncombustible materials. • Majority of ventilation system constructed from noncombustible materials. • Construct the two 10,000-gallon fiberglass reinforced plastic tanks from a resin that provides a flame spread rating of less than 30 based on ASTM E84 test criteria.	• Automatic sprinkler system coverage throughout areas within the Effluent Process Building.	• Combustible control program. • Hot work program. • Prohibiting the storage of the plastic waste storage bags in the Effluent Process Building.
Environmental	• None	• None	• None	• None

3.9 BULK CHEMICAL STORAGE

3.9.1 Process Description

The bulk chemical storage system provides for onsite storage of process chemicals. This includes bulk storage for liquid hydrogen and liquid nitrogen, as well as vaporizers to provide nitrogen and hydrogen to the process. Bulk storage tanks are also provided for concentrated and dilute nitric acid, caustic solution and ammonium hydroxide solution.

Bulk Hydrogen Storage and Vaporization

The bulk hydrogen storage and vaporization system is a package supply system that is owned and maintained by the vendor. The system utilizes a [redacted]gallon horizontal liquid hydrogen tank for storage and a manifold type vaporizer to provide hydrogen gas pressure to the system. The tank is located remotely from the Oxide Conversion Building (OCB) for safety reasons and is protected by a security fence. The system will be routinely monitored by plant personnel for level and other key parameters. Operational, maintenance and safety issues for the system are provided by the vendor.

Bulk Nitrogen Storage and Vaporization

The bulk nitrogen storage and vaporization system is a package supply system that is owned and maintained by the vendor. The system utilizes a [redacted]gallon vertical liquid nitrogen tank for storage and a manifold type vaporizer to provide nitrogen gas pressure to the system. The tank is located next to the OCB. The system will be routinely monitored by plant personnel for level and other key parameters. Operational, maintenance and safety issues for the system are provided by the vendor.

Concentrated and Dilute Nitric Acid Storage Tanks, TK-CNA and TK-DNA

Concentrated (60%) nitric acid is received by truck and stored outside the OCB in tank TK-CNA. TK-CNA is a [redacted]allon tank equipped with level indication. A pump supplies acid to the process via the concentrated acid header and supplies acid, as required, to the Dilute Nitric Acid Storage Tank, TK-DNA. Minimum flow is provided through a recirculation line and restriction orifice back to TK-CNA to prevent dead-heading the pump.

Deionized water is added to TK-DNA to dilute nitric acid strength to [redacted]roximately 10% concentration for use in other process systems. TK-DNA is a [redacted]allon tank equipped with level indicator. A pump supplies acid to the dilute acid header. Minimum flow is provided through a recirculation line and restriction orifice back to TK-DNA to prevent dead-heading the pump.

Sodium Hydroxide Solution Storage Tank, TK-SH

Sodium hydroxide solution (50%) is received by truck and stored outside the OCB in tank TK-SH. TK-SH is a [redacted]gallon tank equipped with a level indicator. Caustic solution is pumped to the caustic solution header. Minimum flow is provided through a recirculation line and restriction orifice back to the tank to prevent dead-heading the pump. Tank temperature is controlled and tank outlet piping is heat-traced to maintain flowability of the sodium hydroxide solution.

Ammonium Hydroxide Solution Storage Tank, TK-AH

Ammonium Hydroxide solution (45%) is received by truck and stored outside the OCB in tank TK-AH. TK-AH is a[redacted]gallon tank equipped with a level indicator. Ammonium hydroxide is pumped to the ammonium hydroxide header. Minimum flow is provided through a recirculation line and restriction orifice back to tank TK-AH to prevent dead-heading the pump. Ammonium hydroxide recycle from the Ammonia Recovery Process is returned to tank TK-AH. The tank is vented to the ammonia recovery scrubber.

3.9.2 Hazard Identification and Controls (Bulk Chemical Storage)

A summary table of hazards and controls for Bulk Chemical Storage is included as Table 3-9. As discussed in the following sections, the only hazards of concern are chemical hazards (worker and public).

3.9.2.1. Chemical Hazards and Controls – Worker (Bulk Chemical Storage)

Chemicals in the bulk chemical storage process include:

- Concentrated (60%) nitric acid.
- Dilute (10%) nitric acid.
- Ammonium hydroxide solution (45%)
- Liquefied hydrogen and nitrogen gases
- Sodium hydroxide

Chemical Reactions:

There are no bulk chemical reactions in this process.

Chemical Hazards:

Chemical spills of all process solutions were analyzed. Spills of ammonium hydroxide from bulk storage or associated equipment have the potential to exceed the ERPG-3 level for ammonia exposure. This has the potential to be a high consequence event. Spills of concentrated nitric acid have the potential to exceed the ERPG-3 level for nitric acid (high consequence event). Leaks and ruptures are prevented by ensuring that the equipment is designed with compatible materials of construction and by periodic inspection to ensure equipment is properly maintained. Overflow situations during bulk tank filling are prevented by operator training to ensure that operators monitor the amount filled and the available storage volume to prevent excessive filling and by operator response to tank high level alarms. Potential leaks due to pump damage that could occur from running a pump blocked in are prevented by ensuring that the pump recirculation line is always open and available during pump operation. This is accomplished by operator training and procedures, and by using a tamper seal on the concentrated acid and ammonium hydroxide bulk storage pumps to prevent inadvertent isolation of the pump recirculation line.

The inadvertent addition of concentrated acid to the dilute nitric acid header has the potential for high consequences due to the potential for a violent reaction if ion exchanger resin were to be exposed to sufficiently high concentration acid. This is prevented by using proper operating procedures and process monitoring during the dilute acid production process and by interlocking closed the dilute acid supply valve if the dilute acid concentration becomes too high.

<u>Chemical Controls:</u>

Passive Engineered Controls

- Compatible materials of construction

Active Engineered Controls

- High concentration interlocks to shut off supply to the dilute acid header

Administrative Controls

- Periodic inspections to ensure system components are properly maintained
- Tank high level alarms on the Central Control System (CCS)
- Tamper seal on recirculation line isolation valves
- Operating procedures and training prevent pump dead head operation
- Operating procedures and training for dilute nitric acid production
- Operator procedures and training on tank filling operations

Other provisions for managing the safe handling 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 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 interlocks, containment, ventilation, detection methods, and/or materials of construction.

In addition, all process chemical handling is done within process equipment; and, process controls, alarm and interlocks are used to assist the operator in properly maintaining process conditions and ensuring that a potentially hazardous upset condition is avoided.

3.9.2.2. Environmental Hazards and Controls Public (Bulk Chemical Storage)

The environmental hazards for the OCB/EPB Bulk Chemical Storage Process are the hazardous chemicals 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. For the Bulk Chemical Storage Process, the following chemical hazards were evaluated to determine if they had the potential to exceed the performance criteria in 10 CFR 70.61 under postulated accident conditions:

<u>Chemical Hazards:</u>

Chemical spills of all process solutions were analyzed. Spills of ammonium hydroxide from bulk storage or associated equipment have the potential to exceed the ERPG-2 level for ammonia exposure. Unmitigated, this has the potential to be a high consequence event. Uncontained and unmitigated spills of concentrated nitric acid have the potential to exceed the ERPG-2 level for nitric acid. Unmitigated, this has the potential to be a high consequence event. Uncontained and unmitigated spills of dilute nitric acid have the potential to exceed the ERPG-1 level for nitric acid. Unmitigated, this has the potential to be an intermediate consequence event. Leaks and ruptures are prevented by ensuring that the equipment is designed with compatible materials of construction and by periodic inspection to ensure equipment is properly maintained. Overflow situations during bulk tank filling are prevented by operator training to ensure that operators monitor the amount filled and the available storage volume to prevent excessive filling and by operator response to tank high level alarms. Potential leaks due to pump damage that could occur from running a pump blocked in are prevented by ensuring that the pump recirculation line is always open and available during pump operation. This is accomplished by operator training and procedures, and by using a tamper seal on the concentrated acid and ammonium hydroxide bulk storage pumps to prevent inadvertent isolation of the pump recirculation line.

Chemical Controls:

Passive Engineered Controls

- Compatible materials of construction

Administrative Controls

- Periodic inspections to ensure system components are properly maintained
- Tank high level alarms on the Central Control System (CCS)
- Tamper seal on recirculation line isolation valves
- Operating procedures and training prevent pump dead head operation
- Operator procedures and training on tank filling operations

Table 3-9
Hazard Summary for the Bulk Chemical Storage Process

Hazard Type	Hazard Description	Passive Eng. Controls	Active Eng. Controls	Admin. Controls
Criticality	• None	• N/A	• N/A	• N/A
Chemical Worker	• Acid fumes • Ammonia fumes	• Compatible materials of construction	• High concentration interlocks to shut off supply to the dilute acid header	• Periodic inspections • Tank high level alarms • Tamper seals on recirculation line isolation valves • Operating procedures on pump operation • Operating procedures on tank filling • Operating procedures on dilute nitric acid production
Radiological	• None	• N/A	• N/A	• N/A
Fire and Explosion	• None	• N/A	• N/A	• N/A
Chemical Environmental	• Acid fumes • Ammonia fumes	• Compatible materials of construction		• Periodic inspections • Tank high level alarms • Tamper seals on recirculation line isolation valves • Operating procedures on pump operation • Operating procedures on tank filling

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 OCB/EPB 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 is 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 (UNH feed, Uranium Precipitation, Drying/Calcining, Powder Handling and Blending, Uranium Recovery, Uranium Dissolution, Ammonia Recovery, Liquid Waste Handling, Bulk Chemical Handling and Storage, Natural Uranium Solution Production and Storage and Balance of Plant Operations.). The ISA Team used the Hazard and Operability (HAZOP) Method to evaluate the process hazards. In performing the PHA, the team evaluated all credible system and component failures based on Piping and Instrumentation Diagram (P&ID) and facility layout 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 engineered (passive or 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). All potential criticality scenarios were conservatively assumed to be high consequence events. 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 HAZOP hazards analysis. The criticality scenarios considered credible for the OCB/EPB 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.

4.2.2 Chemical Safety Consequence Analysis (Worker)

Consequence evaluations for worker Chemical Exposures were performed for the scenarios identified in the PHA. 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. Upon completion of the consequence evaluations, each credible accident scenario was assigned an unmitigated, uncontrolled consequence category based on 10 CFR 70.61 as shown below.

- High consequences – A worker receiving a concentration in excess of the ERPG-3 limit.
- Intermediate consequences – A worker receiving a concentration greater than the ERPG-2 limit but less than or equal to the ERPG-3 limit
- Low Consequence – Consequences that are not high or intermediate.

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 and EPRG values used to establish High and Intermediate levels for chemicals used in the process.

Consequences were evaluated using computer modeling or hand calculations, as appropriate to the scenario. Computer spreadsheet models were developed based on guidance from NUREG/CR-6410 "Nuclear Fuel Cycle Facility Accident Analysis Handbook" and other references as specified in NFS procedures.

General Assumptions for outside 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. If other volume is used, volume is taken from the process description information from engineering documentation and noted in the consequence evaluation documentation.

- Assume unmitigated spill, no credit taken for dikes or berms that are not permanent parts of the building or structure.

- 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.

- Assume 5 minute exposure to liquid pool consisting of total loss of contents of source, unless otherwise specified. Vaporization rate was determined by using 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 95 degrees 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 other published data, or from engineering calculation based on approved reference).

- Assume tank or column size listed in engineering documentation

For spill scenarios inside buildings, consequences were 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. If other volume is used, volume is taken from the process description information from engineering documentation and noted in the consequence evaluation documentation.

- Where columns exist in a bank, are valved together, and are indicated as normally open on the P&ID, loss of bank contents was assumed.

- 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.

- Assume unmitigated spill, no credit taken for dikes or berms that are not permanent parts of the building or structure.

- 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.

- Assume no credit for operator intervention, procedural spill clean up instructions, or respiratory protection in initial consequence evaluation.

- Assume inside temperature of 70 degrees 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 other published data, or from engineering calculation based on approved reference).

- Assume building volume as listed in engineering documentation.

- Assume tank or column size listed in engineering documentation.

Chemical Toxicity (Soluble Uranium)

The chemical toxicity consequence evaluations are presented in the Radiological Consequences Sections 4.2.3 and 4.2.5. 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 acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed material that could endanger the life of the worker. As per DOE-STD-1136-2000 "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities," an acute intake of > 230 mg soluble uranium results in 50% lethality. Therefore, events that result in 230 mg soluble uranium intake or greater by the worker are designated as a high consequence.

- Intermediate Consequence – Events that are not high consequence that result 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. As per DOE-STD-1136-2000 "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities," an acute intake of 40 mg soluble uranium is the threshold for permanent renal damage. Therefore, events that result in 40 mg soluble uranium worker intake or greater, but less than 230 mg, are designated as an intermediate consequence.

- Low Consequence – Consequences that are not high or intermediate

The airborne concentration of the event is calculated utilizing the methods discussed for Occupational Health Physics evaluations. When soluble compounds of uranium (Class D and Class W) are involved with a scenario, the total worker soluble uranium intake is estimated using the calculated uranium airborne concentration, the volume of air inhaled based on reference man inhalation rate of 2E+04 ml/min as specified by 10 CFR 20, Appendix B, and a five minute exposure time, divided by the specific activity of the uranium isotope. When several isotopes of soluble uranium are involved, the total intake is the sum of the intakes for individual isotopes.

For all of the credible chemical consequence scenarios, bounding chemical consequence evaluations were developed. The specific chemical scenarios from the PHA were grouped under one of the bounding evaluations. This information is presented in Table 4-1.

Table 4-1

Chemical Safety Consequence Analysis Summary (Worker)

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
1	[redacted] gallon spill from tank Tk-20 resulting in release of acid fumes	1.1.1.2, 1.1.3.1, 1.3.1.1, 1.8.2.1, 1.11.1.1, 1.14.1.1, 1.14.1.2, 1.15.1.1, 1.16.1.1, 1.17.1.1, 40.8.1.1	Low
2	[redacted] gallon spill from tank Tk-21 resulting in release of acid fumes	1.1.1.2, 1.1.3.1, 1.3.1.1, 1.8.2.1, 1.11.1.1, 1.14.1.1, 1.14.1.2, 1.15.1.1, 1.16.1.1, 1.17.1.1	Low
3	Rupture of 23% ammonia supply header resulting in a [redacted] gallon spill and release of ammonia fumes	2.24.1.1	High
4	[redacted] gallon spill from tank Tk-22 resulting in release of ammonia fumes	2.1.2.1, 2.3.2.2, 2.4.2.2, 2.9.2.1, 2.11.2.2	Low
5	[redacted] gallon spill from tank Tk-23 resulting in release of ammonia fumes	3.1.2.1, 3.1.2.2, 3.1.5.2, 3.3.1.1, 3.8.2.1, 3.9.2.1, 3.14.1.1, 3.24.1.1, 3.24.1.6	Low
6	[redacted] gallon spill from centrifuge resulting in release of ammonia fumes	4.9.3.1	Low
7	[redacted] gallon spill from tank Tk-38 resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 9.1.1.1, 9.8.1.1, 9.17.4.1, 9.17.5.1, 9.17.6.1, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	High
8	[redacted] gallon spill from tank Tk-40 resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 17.1.1.1, 17.1.3.1, 17.3.1.1, 17.8.2.1, 17.14.2.1, 17.17.1.1, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	High

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
9	[redacted] gallon spill from tank Tk-41 resulting in release of ammonia fumes	18.1.1.1, 18.1.2.1, 18.1.6.1, 18.1.8.1, 18.3.1.1, 18.4.4.1, 18.8.1.1, 18.9.1.1, 18.12.2.1, 18.14.1.1, 18.14.1.2, 18.17.1.1	Low
10	[redacted] gallon spill from cross flow filter resulting in release of ammonia fumes	18.17.1.1	Low
11	[redacted] gallon spill from tank Tk-43 resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 18.14.2.1, 18.14.2.2, 20.1.1.1, 20.3.1.1, 20.8.2.1, 20.14.2.1, 20.17.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	High
12	[redacted] gallon spill from Ion Exchanger column resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 21.1.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1, 49.1.7.1	High
13	[redacted] gallon spill from tank Tk-46 A & B resulting in release of acid fumes	22.1.1.1, 22.1.2.1, 22.3.1.1, 22.8.1.1, 22.8.2.1, 22.8.3.1, 22.8.4.1, 22.9.1.1, 22.12.1.1, 22.17.1.1, 22.17.1.6	Low
14	[redacted] gallon spill from tank Tk-47-A resulting in release of acid fumes	23.3.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1, 23.17.1.1, 40.8.2.1	Low
15	[redacted] gallon spill from tank Tk-47-B resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 23.3.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1, 23.17.1.1	High
16	[redacted] gallon spill from scrap dissolver tanks Tk-76 A&B resulting in release of acid fumes (note that NOx is also evolved, such that when the dissolver is in operation, this scenario is bounded by # 17	Scrap dissolver acid fumes bounded by NOx fumes. See Chem #17.	Intermediate

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
17	Release of scrap dissolver off gases due to spill or damage to off gas lines resulting in leak of NOx vapors	40.3.1.1, 40.3.2.4, 40.6.2.3, 43.1.3.1, 43.1.8.1, 43.5.3.1, 43.17.2.1, 43.18.1.1	High
18	[redacted]allon spill from tank Tk-76R resulting in release of acid fumes	40.25.2.2	Low
19	[redacted]llon spill from tank Tk-78 resulting in leak of acid fumes	43.1.4.2, 43.1.5.2, 43.1.9.1, 43.1.10.1, 43.1.14.1, 43.1.15.1, 43.3.4.1	Low
20	[redacted]allon leak from natural dissolver tank Tk-70 resulting in release of acid fumes	38.1.2.1, 38.1.11.1, 38.1.12.1, 38.3.4.1, 38.3.5.1, 38.3.5.2, 38.4.1.1, 38.7.3.1, 38.8.1.1, 38.8.2.2, 38.11.1.1, 38.17.1.1	Low
21	[redacted]allon leak from the 60% nitric acid header in the OCB as a result of line leak	40.25.5.1	Intermediate
22	Release of dryer off gas to the room resulting in release of ammonia fumes	5.1.5.1, 5.1.7.1, 5.1.8.1, 5.1.10.1, 5.3.2.1, 5.3.3.1, 5.3.4.1, 5.3.5.1, 5.12.2.1, 5.12.2.2, 7.1.1.1, 7.1.3.1, 7.1.9.1, 7.3.1.1, 7.3.2.1, 7.14.1.1, 7.14.2.1, 7.17.4.2, 7.18.1.1, 7.18.1.11, 7.18.2.1, 7.18.2.11, 7.19.2.3, 7.19.3.3, 7.19.5.1, 9.17.1.1	Low
23	Release of calciner off gas to the room resulting in release of ammonia and hydrogen to the room. (Hydrogen release is considered bounding with high consequence potential)	5.1.5.2, 5.3.1.1, 5.12.1.1, 6.1.3.1, 6.1.5.1, 6.1.6.1, 6.1.7.1, 6.1.11.1, 6.1.12.1, 6.1.13.1, 6.2.2.1, 6.2.3.1, 6.2.4.1, 6.2.5.5, 6.12.2.1, 7.1.3.5, 7.17.9.2, 7.18.2.2, 7.18.2.5, 7.19.3.4, 7.19.3.7	High

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
24	[redacted] gallon leak from tank Tk-50 resulting in release of ammonia fumes	25.1.2.1, 27.9.1.3	Intermediate
25	[redacted] gallon leak from tank Tk-51 resulting in release of ammonia fumes	25.4.2.1, 25.21.1.1	Intermediate
26	[redacted] gallon leak from heat exchanger E-51 resulting in release of ammonia fumes	Bounded by Chem # 27	High
27	Leak from ammonia recovery column (V-52), overhead condenser (E-53), distillate tank (Tk-54) or associated equipment. Consequences assumed to be high without calculation due to high temperature and ammonia concentration in process solution.	27.1.3.1, 27.1.4.1, 27.1.5.1, 27.1.6.1, 27.9.1.1, 27.17.1.1	High
28	Spill of effluent waste solution containing 20 ppm ammonia covering entire EPB building floor. (Bounds spills from Tk-60, Evaporator, Tk-64, Tk-66 and Mixer)	30.1.2.1, 30.1.3.1, 30.1.4.1, 30.1.5.1, 30.1.8.1, 30.1.9.1, 30.1.10.1, 30.6.4.1, 30.9.3.1, 30.9.4.1, 30.17.2.1, 30.18.1.1, 35.3.1.1, 35.4.1.1, 35.7.1.2, 35.9.1.1, 35.10.1.1, 35.21.2.1, 35.21.3.1, 35.21.4.1, 35.21.5.1, 36.1.1.1, 36.1.2.1, 36.1.2.2, 36.1.3.1, 36.1.6.1, 36.1.7.1, 36.1.9.1, 36.3.1.1, 36.4.3.1, 36.6.2.1	Low
29	[redacted] gallon header leak from pH correction line containing dilute nitric acid to EPB floor	30.17.3.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
30	Leak from 60% nitric Acid Bulk Storage Tank to tank containment area resulting in release of acid fumes	49.1.2.1, 49.1.11.1	Low
31	Leak from dilute acid bulk storage tank to tank containment area resulting in release of acid fumes	49.22.1.2	Low
32	Leak from ammonium hydroxide bulk storage tank to tank containment area resulting in release of ammonia fumes	27.9.1.2, 47.1.5.2, 47.3.1.1	High
33	Explosion of ammonium nitrate solution in systems containing significant amounts of ammonium nitrate solution (>1% weight) Systems include Tk-22, Tk-23, Centrifuge, Tk-38, Tk-40, Tk-41, cross flow filter, Tk-43, Ion Exchangers, Tk-47A and Tk-50	2.1.1.1, 3.1.7.1, 9.1.2.2, 17.1.7.1, 18.1.7.1, 20.1.6.1, 23.1.5.1, 25.1.1.1	High
34	Spill of ammonium nitrate solution	2.1.2.1, 3.1.2.1, 4.9.3.1, 9.1.1.1, 17.1.1.1, 18.1.1.1, 18.17.1.1, 20.1.1.1, 21.1.1.1, 23.3.1.1, 25.1.2.1	Low
35	Spill of sodium nitrate solution	30.1.2.1, 30.1.3.1, 30.1.4.1, 30.1.5.1, 30.1.8.1, 30.1.9.1, 30.1.10.1, 30.6.4.1, 30.9.3.1, 30.9.4.1, 30.17.2.1, 30.18.1.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
36	Spill of sodium hydroxide solution	48.1.1.1, 48.1.4.1, 48.1.5.1, 48.1.5.2, 48.3.1.1, 48.21.1.1	Low
37	Spill of boiler treatment chemical solutions	50.14.2.1	Low
38	Release of ammonia vapors from tank Tk-47B due to boiling during a fire in the tank gallery	FHA Fire Scenario 4	High
39	Release of ammonia vapors from tank Tk-23 due to boiling during fire on the OCB second floor	FHA Fire Scenario 5	High
40	Release of ammonia vapors due to damage to ARF equipment during a fire in the EPB	FHA Fire Scenario 6	High
41	Release of fumes due to loss of seal on overflow leg on tank Tk-38	9.1.6.1, 9.9.1.1, 9.13.1.1, 9.17.7.1, 9.17.3.1	Low
42	Release of fumes due to loss of seal on overflow leg on tank Tk-40	17.9.1.1	Low
43	Release of fumes due to loss of seal on overflow leg on tank Tk-43	20.1.2.1, 20.9.1.1	Low
44	Release of fumes due to loss of seal on overflow leg on tank Tk-47B	23.1.3.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
45	Release of fumes due to loss of seal on overflow leg on tank Tk-50	25.1.3.1, 25.11.1.1	Low
46	Release of fumes due to loss of seal on overflow leg on tank Tk-51	25.1.3.1, 25.11.1.1	Low
47	Spill from rupture of outside 60% nitric acid supply line that results in emptying the bulk storage tank to the ground	49.21.2.1	High
48	Spill from rupture of outside dilute nitric acid supply line that results in emptying the bulk storage tank to the ground	49.21.3.2	Low
49	Spill from rupture of outside 23% aqua ammonia supply line that results in emptying the bulk storage tank to the ground	47.16.1.1	High
50	[redacted]allon spill of dilute nitric acid from dilute acid supply header in the OCB	38.25.3.1	Low
51	Failure of Acid POG system and resultant leak of acid fumes to the room and/or to the environment.	8.1.2.1, 8.17.1.1, 8.17.2.1, 8.17.3.1, 8.17.4.2, 8.17.5.1, 8.19.2.1, 8.19.3.1, 8.19.4.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
52	Failure of Base POG system and resultant leak of ammonia fumes to the room and/or to the environment.	Leaks to room bounded by evaluation Chem-7	Intermediate
53	Failure of nuisance fume blower on the 60% nitric acid bulk tank during offloading operations.	49.1.6.1, 49.1.6.2	Low
54	Leak in vent system for the base tank header and resultant leak of ammonia fumes to the room	7.17.7.1	Low
55	NOx release due to addition of drum of enriched scrap material to natural dissolver	38.7.1.2	High
56	Outdoor [redacted] gallon leak of UNH solution from transfer line between UNB and OCB	1.17.1.1, 38.25.5.1	Low
57	Outdoor [redacted] gallon leak of liquid waste from ion exchanger effluent line to EPB	25.21.1.2	High
58	FHA general area fire scenarios in areas that do not contain equipment with potentially hazardous chemicals	FHA Scenario #1 FHA Scenario #2 FHA Scenario #3	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Occupational consequences
59	FHA explosion and torch fire scenarios related to hydrogen in the calciner off gas and related equipment	FHA Scenario #7 FHA Scenario #8 FHA Scenario #9 FHA Scenario #10	High
60	Uranium toxicity scenario related to radiological accident consequence analysis evaluations: OCB-RWC-12 OCB-RWC-15	38.7.1.2, 38.25.1.1	Intermediate
61	Uranium toxicity scenario related to radiological accident consequence analysis evaluations: OCB-RWC-13 OCB-RWC-14 OCB-RWC-16 OCB-RWC-17 OCB-RWC-18	38.1.2.3, 38.1.11.1, 38.1.12.1, 38.1.20.3, 38.3.1.2, 38.3.2.2, 38.3.4.1, 38.3.5.1, 38.3.5.2, 38.7.3.1, 38.8.1.1, 38.8.2.2, 38.11.1.1, 38.17.1.2, 38.17.1.5, 38.25.8.1, 40.1.3.1, 40.1.6.1, 40.1.8.1, 40.1.13.1, 40.3.1.1, 40.3.2.1, 40.3.2.2, 40.3.2.3, 40.3.2.4, 40.3.3.1, 40.3.6.1, 40.3.7.1, 40.3.9.1, 40.3.10.1, 40.3.10.2, 40.3.11.1 40.3.13.1, 40.3.14.1, 40.6.2.3, 40.8.1.1, 40.8.2.1, 40.12.2.1, 40.14.1.1, 40.14.1.2, 40.15.1.1, 40.15.1.2, 40.25.1.2, 40.25.2.2, 40.25.4.1, 40.25.6.2, 40.25.9.1, 40.26.2.1, 43.1.1.1, 43.1.3.1, 43.1.4.2, 43.1.5.2, 43.1.6.1, 43.1.7.1, 43.1.8.1, 43.1.9.1, 43.1.10.1, 43.1.13.1, 43.1.14.1, 43.1.15.1, 43.3.1.1, 43.3.1.2, 43.3.2.1, 43.3.4.1, 43.5.3.1, 43.5.4.1, 43.6.1.2, 43.6.2.1, 43.17.1.1, 43.17.2.1, 43.18.1.1 UNB Node 14 (9.1.1, 9.1.2, 9.7.1, 9.8.1)	Low

4.2.3 Radiological Safety Consequence Analysis (Worker)

The accident scenarios for evaluation are provided on tables developed by a qualified ISA team during a Process Hazard Analysis, as specified in NFS-GH-55, "Integrated Safety 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. As per NFS-HS-A-68 "ISA Risk Assessment Program", the methods used for consequence evaluation are acceptable if the methods and calculations are consistent with the referenced approaches, they are scientifically correct as a reasonable estimate, and the use of generic assumptions and data is reasonably conservative for the types of accidents analyzed. 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

The following is a generalized summary of the methodology utilized for the OCB/EPB Occupational Health Physics Consequence Analysis.

For uranium processing, the dose from the inhalation pathway will dominate the Total Effective Dose Equivalent (TEDE). A potential airborne release of radioactive material can occur in the OCB/EPB process if one of the following types of stress is imposed: thermal stress, explosive release (i.e., pressurized venting effects, shock effects, blast effects), free-fall spills and aerodynamic entrainment and resuspension.

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, 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 Dispersion Coefficients

The second step of the inhalation calculation methodology utilizes dispersion modeling to determine the concentration of the dispersed source term at the location of the worker. The dispersion coefficient for the worker is calculated by assuming that the quantity of released material is dispersed into a volume equal to the volume of building or room in which the accident occurs. Due to the large number of variables associated with atmospheric dispersion modeling at locations near the point of release, consequences of occupationally exposed individuals due to outdoor releases are conservatively considered bound by the loss of material containment inside the building.

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 MEI 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 isotope. The total uranium intake is the sum of the intakes for the individual uranium isotopes. The worker uranium intake 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)

Worker External Exposure Methodology

Although the primary pathway for personnel exposure is an internal exposure pathway, exposure to direct radiation contributes to the Total Effective Dose Equivalent (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 (25 rem $\leq$ TEDE < 100 rem) or high (TEDE $\geq$ 100 rem) consequence determination.

The external dose calculations were performed using MicroShield version 5.03. Each isotope 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 isotope. The form of the radioactive and the type of container in which the material is present will also impact the exposure potential. Therefore, for conservatism, each isotope 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 isotopes, 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.

Table 4-2

Radiological Safety Consequence Analysis Summary (Worker)

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
OCB-RWC-1	Overall Vessel Failure of Centrifuge and Subsequent Spill [redacted] gallons low enriched solution/slurry Tank Gallery dilution volume (4.1.3.1)	1.1.1.2, 1.1.2.1, 1.1.2.2, 1.1.3.1, 1.1.4.1, 1.1.4.2, 1.3.1.1, 1.6.2.1, 1.6.3.1, 1.8.1.1, 1.8.2.1, 1.9.1.1, 1.9.2.1, 1.10.1.1, 1.14.1.1, 1.14.1.2, 1.14.1.3, 1.17.1.2, 1.17.1.5, 2.1.1.1, 2.1.2.1, 2.1.2.2, 2.3.1.2, 2.3.1.3, 2.3.2.2, 2.3.2.3, 2.4.2.2, 2.4.3.2, 2.6.3.1, 2.6.4.1, 2.8.1.1, 2.8.1.2, 2.9.1.1, 2.10.1.1, 2.14.1.1, 2.14.1.2, 2.14.1.3,2.24.1.2, 2.24.1.5, 2.24.1.6, 3.1.2.1, 3.1.2.2, 3.1.3.1, 3.1.4.2, 3.1.5.1, 3.1.5.2, 3.1.7.1, 3.3.1.1, 3.4.2.1, 3.6.1.1, 3.6.3.1, 3.8.2.1, 3.8.2.2, 3.9.1.1, 3.9.2.1, 3.10.1.1, 3.12.1.1, 3.14.1.1, 3.14.1.2, 3.14.1.3, 3.24.1.2, 3.24.1.5, 3.24.1.6, 4.1.1.2, 4.1.3.1, 4.1.4.1, 4.9.3.1, 4.20.1.1 *UNB Node 13 (1.123.1, 1.123.2, 1.127.1, 1.129.1, 1.130.1) Fire scenario 4 (OCB Tank Gallery Fire)	Low
OCB-RWC-2	Aerodynamic Entrainment & Resuspension [redacted] gallons low enriched solution/slurry Tank Gallery dilution volume (1.11.1.1)	1.11.1.1, 2.11.1.1	Low
OCB-RWC-3	Overall Vessel Failure of IX Columns Tank Gallery dilution volume (2.26.1.2)	2.26.1.2, 3.1.1.2, 3.6.2.2, 4.3.1.2,21.7.1.1,21.18.1.2	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
OCB-RWC-4	Overall vessel failure/blowout of 183 L ADU Dryer (V-30) and a free-fall spill of ADU slurry from the ADU centrifuge at 135.4 kg/hr (45.1 l/hr at 3 g/cc ADU density) subsequently released. (5.18.3.2)	5.1.1.1, 5.1.2.1, 5.1.3.1, 5.1.4.1, 5.1.5.1, 5.1.6.1, 5.1.7.1, 5.1.8.1, 5.1.10.1, 5.3.2.1, 5.3.3.1, 5.3.4.1, 5.3.5.1, 5.12.2.1, 5.12.2.2, 5.18.3.2, 5.18.4.1, 6.18.1.1, 7.1.1.1, 7.1.3.1, 7.1.3.11, 7.1.9.1, 7.1.11.1, 7.3.1.1, 7.3.2.1, 7.10.4.1, 7.10.4.2, 7.14.1.1, 7.14.2.1, 7.18.1.1, 7.18.1.11, 7.18.2.1, 7.18.2.2, 7.18.2.11, 7.19.2.3, 7.19.3.2, 7.19.3.3, 7.19.5.1, 7.19.5.11,8.4.2.1,8.10.1.1,8.17.2.1,8.17.3.1,8.17.5.1,9.1.1.1, 9.1.2.1, 9.1.3.1, 9.1.4.1, 9.1.6.1, 9.3.1.2, 9.4.1.2, 9.8.1.1, 9.9.1.1, 9.13.1.1, 9.17.1.1, 9.17.3.1, 9.17.4.1, 9.17.5.1, 9.17.5.2, 9.17.6.1, 9.17.6.2, 9.17.7.1, 9.17.8.1, 9.17.8.11	Low
OCB-RWC-5	Aerodynamic entrainment and resuspension of 743 L low enriched UO_2/U_3O_8 powder 1st Floor Conversion Area	6.11.1.1, 6.18.2.1, 6.18.3.1, 6.18.7.1, 6.18.8.1, 6.2.10.1, 6.2.9.1, 7.19.3.2, 8.17.1.1, 8.19.1.2, 9.17.2.1, 10.1.9.1, 10.1.15.5, 10.11.1.1, 10.17.1.1, 10.17.2.1, 11.1.2.3, 11.1.3.3, 11.1.4.1, 11.1.5.1, 11.3.3.3, 11.3.2.4, 11.17.1.1, 11.17.3.1, 12.17.6.1, 12.19.3.2, 12.19.3.3, 15.1.4.1, 16.1.10.1, 16.1.7.1, 16.16.1.2, 16.18.1.1, 16.18.1.2	Low
OCB-RWC-6	Free-fall spill of 99 L low enriched UO_2/U_3O_8 powder 1st Floor Conversion Area	10.11.3.1, 10.17.3.1, 11.1.3.2, 11.3.2.2, 11.3.2.3, 11.3.3.2, 11.5.2.1, 11.10.1.1, 11.11.1.1, 12.3.9.1, 12.16.1.2, 12.16.2.2, 12.17.1.1, 12.17.4.2, 12.19.2.2, 15.17.1.1, 16.3.1.1, 16.17.2.2	Low
OCB-RWC-7	Venting or confinement failures of ≤ 235 L low enriched UO_2/U_3O_8 powder 2nd Floor Conversion Area	5.1.11.1, 5.1.15.1, 5.1.5.2, 5.1.7.2, 5.1.8.2, 5.12.1.1, 5.3.1.1, 5.3.2.2, 5.3.3.2, 6.1.3.1, 6.1.4.1, 6.1.5.1, 6.1.6.1, 6.1.7.1, 6.1.11.1, 6.1.12.1, 6.1.13.1, 6.1.14.1, 6.1.17.1, 6.1.18.1, 6.1.19.1, 6.1.20.1, 6.2.2.1, 6.2.3.1, 6.2.5.5, 6.2.6.1, 6.2.7.1, 6.4.3.1, 6.12.2.1, 6.12.4.1, 6.12.5.1, 6.12.6.1, 6.18.6.2, 7.10.4.1, 7.1.1.2, 7.1.2.1, 7.1.3.2, 7.1.3.5, 7.1.9.2, 7.1.9.5, 7.1.11.2, 7.1.11.5, 7.3.1.2, 7.3.1.5, 7.3.2.2, 7.3.2.5, 7.14.1.2, 7.14.1.5, 7.14.2.2, 7.14.2.5, 7.17.11.1, 7.17.12.1, 7.17.4.2, 7.17.5.2, 7.17.6.2, 7.17.7.1, 7.17.8.2, 7.17.9.2, 7.18.1.2, 7.18.1.5, 7.18.2.5, 7.19.2.2, 7.19.2.4, 7.19.2.7, 7.19.3.4, 7.19.3.7, 7.19.5.2, 7.19.5.5, 9.17.8.2, 9.17.8.5, 10.1.12.2, 10.1.13.2, 10.1.6.2, 10.3.3.2, 10.3.6.2, 10.3.7.2, 10.3.9.1, 11.9.1.1, 12.1.11.1, 12.1.12.1, 12.1.13.1, 12.17.5.2, 15.17.2.2, 16.3.3.1, 16.3.4.1, 16.17.3.2	Low
OCB-RWC-7a	Venting or confinement failures of 235 L < material ≤ 943 L low enriched UO_2/U_3O_8 powder 2nd Floor Conversion Area	12.3.2.1	Intermediate
OCB-RWC-7a	Venting or confinement failures of > 943 L low enriched UO_2/U_3O_8 powder 2nd Floor Conversion Area	12.1.8.1, 12.1.9.1, 12.1.10.1, 12.3.3.1, 12.3.5.2, 12.3.8.1	High

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
OCB-RWC-8	Thermal stress of 990 L low enriched UO_2/U_3O_8 powder 1st Floor Conversion Area	5.3.2.5, 6.18.2.4, 6.18.3.4, 6.18.4.1, 6.18.5.2, 6.18.6.1, 6.20.1.1, 6.20.1.2, 7.1.11.10, 7.1.2.6, 7.1.3.10, 7.1.9.10, 7.3.1.10, 7.3.2.10, 7.14.1.10, 7.14.2.10, 7.18.1.10, 7.18.2.10, 7.19.2.12, 7.19.3.12, 7.19.5.10, 9.4.1.1, 9.17.2.4, 9.17.4.4, 9.17.6.4, 9.17.7.2, 9.17.8.10, 9.17.8.12 Fire Scenario 1 (Bounding 1400 KW Fire, First Floor Conversion Area) Fire Scenario 2 (Forklift Propane Torch Fire Exposure to Conversion Area) Fire Scenario 3 (OCB Loading Area Forklift Propane Fuel Fire) Fire Scenario 4 (Conversion Area 2nd Floor Fire)	Low
OCB-RWC-9	High pressure causes overall containment failure of [redacted]allon Tank 47A (23.9.1.3)	17.1.1.1, 17.1.2.1,17.1.4.1, 17.1.7.1, 17.3.1.1, 17.4.1.1, 17.4.2.1, 17.4.3.1, 17.6.4.1,17.9.1.1, 17.9.2.2, 17.10.1.1, 17.12.1.1, 17.12.2.1, 17.14.1.1, 17.14.3.1, 17.17.1.5, 17.17.1.6, 18.1.1.1, 18.1.2.1, 18.1.6.1, 18.1.7.1, 18.3.1.1, 18.4.4.1, 18.6.3.1, 18.8.1.1, 18.9.1.1, 18.12.2.1, 18.14.1.1, 18.14.1.2, 18.17.1.5, 20.1.1.1, 20.1.2.1,20.1.3.1, 20.1.6.1, 20.3.1.1, 20.4.1.1,20.4.2.1, 20.6.4.1, 20.8.1.1, 20.9.1.1, 20.9.1.3, 20.9.3.1, 20.9.3.3, 20.12.2.1, 20.14.1.1, 20.14.1.2, 20.17.1.5,20.17.1.6, 21.1.1.1, 22.1.1.1,22.1.3.1,22.1.4.1, 22.3.1.1, 22.4.1.1, 22.6.3.1, 22.8.1.1, 22.8.2.1, 22.8.3.1, 22.9.1.1, 22.9.1.3, 22.17.1.5, 22.17.1.6, 23.1.3.1, 23.1.4.1, 23.1.5.1, 23.3.1.1, 23.4.1.1, 23.4.2.1, 23.9.1.1, 23.9.1.3, 23.14.1.1, 23.14.2.1, 23.17.1.5, 23.17.1.6	Low
OCB-RWC-10	Overall containment failure of Tank 50 ([redacted]al) and subsequent spill of Tank 51 (500 gal). (25.1.4.1)	25.1.1.1, 25.1.2.1, 25.1.3.1, 25.1.4.1, 25.3.1.1, 25.4.1.1, 25.4.1.2, 25.4.2.1, 25.4.2.2, 25.4.3.1, 25.4.3.2, 25.9.1.1, 25.11.1.1, 25.14.1.1, 25.14.1.2., 25.19.1.1, 25.21.1.1,25.21.1.2, 25.21.1.4, 27.1.1.1, 27.1.1.2, 27.3.1.1, 27.4.4.1, 27.6.3.1,27.9.1.1,27.9.1.3,27.9.2.1,27.9.2.3,27.9.4.1, 27.10.1.1, 27.17.1.1, 27.17.1.4, 27.18.2.1, 27.18.3.2	Low
OCB-RWC-11	Over pressurization and complete failure of TK-64A. Spilling [redacted] gallons in the EPB. (30.9.3.1)	30.1.1.1, 30.1.2.1, 30.1.3.1, 30.1.4.1, 30.1.5.1, 30.1.6.1, 30.1.7.1, 30.1.8.1, 30.1.9.1,30.1.10.1, 30.3.1.1, 30.3.2.1, 30.5.1.1, 30.6.3.1, 30.6.4.1, 30.8.1.1, 30.8.2.1,30.9.2.1, 30.9.3.1, 30.9.4.1, 30.10.1.1, 30.17.2.1, 30.18.1.1, 35.1.3.1, 35.1.4.2, 35.3.1.1, 35.4.1.1, 35.7.1.2, 35.7.2.2, 35.8.1.2, 35.17.1.2, 35.20.1.3, 35.21.4.1, 35.21.5.1, 35.23.2.1, 36.1.1.2, 36.1.2.1, 36.1.2.3, 36.1.3.2, 36.1.4.2, 36.1.6.1, 36.1.7.1, 36.1.9.2, 36.3.1.1, 36.3.2.1, 36.4.1.1, 36.6.1.1, 36.17.1.1 Fire Scenario 6 (Effluent Building Fire)	Low
OCB-RWC-12	Overall containment failure of [redacted] gallon (TK-70) natural uranyl nitrate in OCB (38.7.1.2)	38.7.1.2	Low
OCB-RWC-13	Spill [redacted]allons (TK-70) hot natural uranyl nitrate solution in OCB (38.1.2.3)	38.1.2.3, 38.1.20.3, 38.3.1.2, 38.3.2.2, 38.7.3.1, 38.11.1.1, 38.17.1.2, 38.17.1.5	Low

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
OCB-RWC-14	Spill [redacted] gallon (TK-70 to TK-18 transfer) natural uranyl nitrate solution in UNB (38.1.11.1)	38.1.11.1, 38.1.12.1, 38.3.4.1, 38.8.1.1	Low
OCB-RWC-15	Spill of [redacted] kg drum UO_3 powder in OCB (38.25.1.1)	38.25.1.1	Low
OCB-RWC-16	Outdoor spill of [redacted] gallons natural uranyl nitrate solution (38.3.5.1)	38.3.5.1, 38.3.5.2, 38.8.2.2 *UNB Node 14 (9.1.1, 9.1.2, 9.7.1, 9.8.1)	Low
OCB-RWC-17	Overall containment failure of V-73 resulting in the dispersion of 39.5 l of low enriched UO_2/U_3O_8 powder with 283 gU/l concentration (40.3.13.1)	40.3.13.1, 40.25.4.1	Low
OCB-RWC-18	Overall containment failure of V-76A resulting in a 15 gallon spill of 56.8 l of hot low enriched uranyl nitrate with 283 gU/l concentration (40.25.6.2)	40.1.8.1, 40.3.1.1, 40.3.2.4, 40.3.6.1, 40.3.7.1, 40.3.11.1, 40.6.2.3, 40.8.1.1, 40.8.2.1, 40.15.1.1, 40.15.1.2, 40.25.1.2, 40.25.2.2, 40.25.6.2, 40.25.9.1, 40.26.2.1, 43.1.1.1, 43.1.3.1, 43.1.4.2, 43.1.5.2, 43.1.8.1, 43.1.9.1, 43.1.10.1, 43.1.13.1, 43.1.14.1, 43.1.15.1, 43.3.2.1, 43.3.4.1, 43.5.3.1, 43.17.1.1, 43.17.2.1, 43.18.1.1	Low
NA	Explosion Scenario 1	Hydrogen Explosion in Calciner or Scrubber Off-Gas System	High**
NA	Explosion Scenario 2	Hydrogen Released into 2nd Floor Conversion Area	High**
NA	Explosion Scenario 3	Hydrogen Air-Dilution System Explosion	High**
NA	Explosion Scenario 4	Hydrogen Release and Torch Fire	High**

* Items identified in UNB ISA Summary (21T-03-0664) as covered in OCB ISA Summary
** Accident sequence assumed to lead to High Consequences

4.2.4 Fire Safety Consequence Analysis

Fire hazards for the OCB/EPB were evaluated through the Fire Hazards Analysis (FHA) (Reference 9), and through an unmitigated fire or explosion damage assessment. The potential fire and explosion scenarios identified by the ISA Team in the PHA were provided as input to the FHA. In addition, the FHA examined the potential fire and explosion hazards on a facility basis. The hazards and controls determined through the FHA are summarized in the Fire Hazard Sections of Section 3 (3.1.2.4, 3.2.2.4, etc.). For each process in Section 3, the fire and explosion hazards, along with the required controls, as determined by the FHA are identified. 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.

The fire and explosion scenarios evaluated in the FHA have no criticality consequences. The FHA concludes that there is no structural damage in the Conversion Area and no damage to equipment containing hydrogen based on the modeled bounding fire scenario. There is no damage to the moderation controlled area boundaries permitting the entry of water or damage to equipment structural supports in the conversion or recovery areas leading to increased interaction and potential criticality. Therefore, a criticality is not credible as a result of the bounding fire scenario since moderation cannot be introduced to the ModCon area and the equipment and structural supports remain intact such that the equipment remains in their analyzed configurations.

A hydrogen explosion within the calciner was identified as leading to potential damage to structural building components in the Conversion Area. With management measures, as identified in the FHA, a hydrogen explosion is a highly unlikely event. A hydrogen explosion within the calciner will cause the calciner to vent at both the feed and discharge ends. Further venting is expected to occur though process off-gas filters and connections between the Dryer and Centrifuge. Although structural damage is expected in a hydrogen explosion the pressures are not sufficient to lead to increased vessel dimensions. Structural damage will not lead to increased interaction between the Dryer, Centrifuge and Calciner since this equipment is configured in the same plane. A structural support failure in the Conversion Area allows the vessel to fall to the floor without impacting adjacent equipment or increasing interaction. A hydrogen explosion is expected to lead to the release of fissile material; however the material released is bounded by the spill scenario evaluated in the Conversion Area NCSEs consisting of the release of the entire vessels contents plus 30 minutes of continued release at nominal process flow rates. Therefore, a criticality in the Conversion Area is not credible as a result of a hydrogen explosion within the calciner since it will not lead to increased equipment dimensions, an increase in interaction, or significant material spillage on the floor.

The Fire Safety Consequence Analysis Summary in Table 4-3 identifies the fire and explosion scenarios that were evaluated in the FHA. 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	High, Intermediate or Low Consequence
1	**Bounding 1400KW Fire, First Floor Conversion Area:** The fire is bounded by a 1400 KW office computer workstation fire on the first floor. This fire scenario consists of an office fire exposure to the first floor Conversion Area assuming the fire door between areas is propped open. This fire scenario bounds the fire scenarios for each of the following fuel packages in the first floor Conversion Area: 1) Wood pallets stacked 3 high, 2) Six plastic bags containing combustible trash, 3) Four cardboard boxes containing filters, 4) Polycarbonate LEXAN™ Panels, 5) PE/PVC insulated cables, and 6) polypropylene piping.	See Safety Discipline Evaluations
2	**Forklift Propane Torch Fuel Fire Exposure to Conversion Area:** A forklift fuel torch fire involving 43 pounds of propane fuel at the roll-up door between the Conversion Area and Loading Area ignites transient combustibles near the roll-up door. This fire is bounded by a propane torch fire at 3112 KW with a 1400 KW transient combustible fire following after approximately 5 minutes. This fire scenario bounds the following fuel packages for the transient combustible fire: 1) Wood pallets stacked 3 high, 2) Six plastic bags containing combustible trash, 3) Four cardboard boxes containing filters, 4) Polycarbonate LEXAN™ Panels, 5) PE/PVC insulated cables, 6) polypropylene piping, and 7) Office fire exposure.	See Safety Discipline Evaluations
3	**OCB Loading Area Forklift Propane Fuel Fire:** A forklift fuel torch fire involving 43 pounds of propane in the Loading Area ignites transient combustibles in the loading area. This fire is bounded by a propane torch fire at 3112 KW with a 1400 KW transient combustible fire following after approximately 5 minutes. This fire scenario bounds the following fuel packages for the transient combustible fire: 1) Wood pallets stacked 3 high, 2) Six plastic bags containing combustible trash, 3) Four cardboard boxes containing filters, 4) Polycarbonate LEXAN™ Panels, 5) PE/PVC insulated cables. This assumes the fire door between the Loading Area and the Conversion Area is closed and the door to the truck-loading canopy is open.	See Safety Discipline Evaluations
4	**OCB Tank Gallery Fire:** A transient combustible fire in the tank gallery ignites polypropylene plastic piping. This fire is bounded by a 1400 KW transient combustible fire and a 923 KW polypropylene piping fire. This fire scenario bounds the following fuel packages for the transient combustible fire: 1) Wood pallets stacked 3 high, 2) Six plastic bags containing combustible trash, 3) Four cardboard boxes containing filters, 4) Polycarbonate LEXAN™ Panels, 5) PE/PVC insulated cables	See Safety Discipline Evaluations
5	**Conversion Area 2nd Floor Fire:** This fire is bounded by a 1400 KW office computer workstation fire on the second floor. This fire scenario consists of an office fire exposure to the second floor Conversion Area assuming the second floor door between areas is propped open. This fire scenario bounds the fire scenarios for each of the following fuel packages in the first floor Conversion Area: 1) Wood pallets stacked 3 high, 2) Six plastic bags containing combustible trash, 3) Four cardboard boxes containing filters, 4) Polycarbonate LEXAN™ Panels, 5) PE/PVC insulated cables, 6) polypropylene piping. This fire scenario also bounds the hydrogen torch fire scenario using an equivalent 0.25-inch hole diameter at 5 psi (272 KW).	See Safety Discipline Evaluations

Evaluation Number	Scenario Evaluated	High, Intermediate or Low Consequence
6	Effluent Building Fire: Polypropylene waste storage bags being stored at the building are ignited resulting in a liquid pool fire 10 feet in diameter. This fire scenario bounds the fire scenarios for each of the following transient combustible fuel packages: 1) Wood pallets stacked 3 high, 2) Six plastic bags containing combustible trash, and 3) Four cardboard boxes containing filters.	See Safety Discipline Evaluations
7	Hydrogen Explosion in Calciner or Scrubber Off-Gas System	See Safety Discipline Evaluations
8	Hydrogen Released into Second Floor Conversion Area	See Safety Discipline Evaluations
9	Hydrogen Air-Dilution System Explosion	See Safety Discipline Evaluations
10	Hydrogen Release and Torch Fire	See Safety Discipline Evaluations

4.2.5 Environmental Safety Consequence Analysis

The OCB/EPB 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 OCB/EPB accident scenarios.

4.2.5.1. Environmental Chemical Safety Consequence Analysis

A Process Hazards Analysis was performed on the OCB/EPB in accordance with NFS-GH-55 (Integrated Safety Analysis) by an ISA team. The analysis identified the hazards associated with each area of the OCB/EPB by using the HAZOP 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 Gaussian dispersion modeling to estimate plume concentration and potential exposure concentration level to the public. The vapor generation rate was determined using the vaporization model cited in EPA 560/4-88-002, "Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form". This was then used as the basis for atmospheric dispersion modeling.

Each accident was analyzed for environmental and occupational consequence. As a result, the same methodologies listed in Section 4.2.2 for occupational hazard scenario analysis were used as the basis for fume generation modeling and environmental consequence determination..

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 Engineers' Handbook, CRC Handbook of Chemical and Physical Properties, and published data were used in defining the physical properties used in consequence analysis. Maximum emission values were based on the design process scrubber and ventilation system rates. Fumes generated from a given accident sequence were assumed to discharge to the environment at the design discharge rate. The consequence level was determined by using the maximum downstream concentration under the worst case atmospheric conditions.

Bounding chemical environmental consequence scenarios were developed and the scenarios from the PHA were grouped under a specific bounding consequence evaluation. The grouping of the PHA scenarios and the results of the bounding consequence evaluations are provided in Table 4-4. The assumptions which were used to develop the bounding environmental consequence scenarios are provided in Table 4-5.

Table 4-4
Environmental Chemical Safety Consequence Summary Table

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
1	[redacted] gallon spill from tank Tk-20 resulting in release of acid fumes	1.1.1.2, 1.1.3.1, 1.3.1.1, 1.8.2.1, 1.11.1.1, 1.14.1.1, 1.14.1.2, 1.15.1.1, 1.16.1.1, 1.17.1.1, 40.8.1.1	Low
2	[redacted] gallon spill from tank Tk-21 resulting in release of acid fumes	1.1.1.2, 1.1.3.1, 1.3.1.1, 1.8.2.1, 1.11.1.1, 1.14.1.1, 1.14.1.2, 1.15.1.1, 1.16.1.1, 1.17.1.1	Low
3	Rupture of 23% ammonia supply header resulting in a [redacted] gallon spill and release of ammonia fumes	2.24.1.1	Intermediate
4	[redacted] gallon spill from tank Tk-22 resulting in release of ammonia fumes	2.1.2.1, 2.3.2.2, 2.4.2.2, 2.9.2.1, 2.11.2.2	Low
5	[redacted] gallon spill from tank Tk-23 resulting in release of ammonia fumes	3.1.2.1, 3.1.2.2, 3.1.5.2, 3.3.1.1, 3.8.2.1, 3.9.2.1, 3.14.1.1, 3.24.1.1, 3.24.1.6	Low
6	[redacted] gallon spill from centrifuge resulting in release of ammonia fumes	4.9.3.1	Low
7	[redacted] gallon spill from tank Tk-38 resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 9.1.1.1, 9.8.1.1, 9.17.4.1, 9.17.5.1, 9.17.6.1, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	Low
8	[redacted] gallon spill from tank Tk-40 resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 17.1.1.1, 17.1.3.1, 17.3.1.1, 17.8.2.1, 17.14.2.1, 17.17.1.1, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
9	[redacted] gallon spill from tank Tk-41 resulting in release of ammonia fumes	18.1.1.1, 18.1.2.1, 18.1.6.1, 18.1.8.1, 18.3.1.1, 18.4.4.1, 18.8.1.1, 18.9.1.1, 18.12.2.1, 18.14.1.1, 18.14.1.2, 18.17.1.1	Low
10	[redacted] gallon spill from cross flow filter resulting in release of ammonia fumes	18.17.1.1	Low
11	[redacted] gallon spill from tank Tk-43 resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 18.14.2.1, 18.14.2.2, 20.1.1.1, 20.3.1.1, 20.8.2.1, 20.14.2.1, 20.17.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	Low
12	[redacted] gallon spill from Ion Exchanger column resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 21.1.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1, 49.1.7.1	Low
13	[redacted] gallon spill from tank Tk-46 A & B resulting in release of acid fumes	22.1.1.1, 22.1.2.1, 22.3.1.1, 22.8.1.1, 22.8.2.1, 22.8.3.1, 22.8.4.1, 22.9.1.1, 22.12.1.1, 22.17.1.1, 22.17.1.6	Low
14	[redacted] gallon spill from tank Tk-47-A resulting in release of acid fumes	23.3.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1, 23.17.1.1, 40.8.2.1	Low
15	[redacted] gallon spill from tank Tk-47-B resulting in release of ammonia fumes	2.14.1.3, 3.14.1.3, 18.14.2.1, 18.14.2.2, 20.1.4.1, 20.8.2.1, 20.14.2.1, 23.3.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1, 23.17.1.1	Low
16	[redacted] gallon spill from scrap dissolver tanks Tk-76 A&B resulting in release of acid fumes (note that NOx is also evolved, such that when the dissolver is in operation, this scenario is bounded by # 17	Scrap dissolver acid fumes bounded by NOx fumes. See Chem #17.	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
17	Release of scrap dissolver off gases due to spill or damage to off gas lines resulting in leak of NOx vapors	38.6.1.1, 38.6.2.1, 40.3.1.1, 40.3.2.4, 40.6.2.3, 40.11.1.1, 43.1.2.1, 43.1.3.1, 43.1.5.1, 43.1.8.1, 43.1.12.1, 43.1.15.2, 43.3.2.2, 43.3.5.1, 43.3.7.1, 43.3.8.1, 43.5.1.1, 43.5.2.1, 43.5.3.1, 43.5.3.2, 43.5.4.2, 43.17.2.1, 43.18.1.1	Low
18	[redacted] gallon spill from tank Tk-76R resulting in release of acid fumes	40.25.2.2	Low
19	[redacted] gallon spill from tank Tk-78 resulting in leak of acid fumes	43.1.4.2, 43.1.5.2, 43.1.9.1, 43.1.10.1, 43.1.14.1, 43.1.15.1, 43.3.4.1	Low
20	[redacted] gallon leak from natural dissolver tank Tk-70 resulting in release of acid fumes	38.1.2.1, 38.1.11.1, 38.1.12.1, 38.3.4.1, 38.3.5.1, 38.3.5.2, 38.4.1.1, 38.7.3.1, 38.8.1.1, 38.8.2.2, 38.11.1.1, 38.17.1.1	Low
21	[redacted] gallon leak from the 60% nitric acid header in the OCB as a result of line leak	40.25.5.1	Low
22	Release of dryer off gas to the room resulting in release of ammonia fumes	5.1.5.1, 5.1.7.1, 5.1.8.1, 5.1.10.1, 5.3.2.1, 5.3.3.1, 5.3.4.1, 5.3.5.1, 5.12.2.1, 5.12.2.2, 7.1.1.1, 7.1.3.1, 7.1.9.1, 7.3.1.1, 7.3.2.1, 7.14.1.1, 7.14.2.1, 7.17.4.2, 7.18.1.1, 7.18.1.11, 7.18.2.1, 7.18.2.11, 7.19.2.3, 7.19.3.3, 7.19.5.1, 9.17.1.1	Low
23	Release of calciner off gas to the room resulting in release of ammonia and hydrogen to the room. (Hydrogen release is considered bounding with high consequence potential)	5.1.5.2, 5.3.1.1, 5.12.1.1, 6.1.3.1, 6.1.5.1, 6.1.6.1, 6.1.7.1, 6.1.11.1, 6.1.12.1, 6.1.13.1, 6.2.2.1, 6.2.3.1, 6.2.4.1, 6.2.5.5, 6.12.2.1, 7.1.3.5, 7.17.9.2, 7.18.2.2, 7.18.2.5, 7.19.3.4, 7.19.3.7	Intermediate

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
24	[redacted] gallon leak from tank Tk-50 resulting in release of ammonia fumes	25.1.2.1, 27.9.1.3	Low
25	[redacted] gallon leak from tank Tk-51 resulting in release of ammonia fumes	25.4.2.1, 25.21.1.1	Low
26	[redacted] gallon leak from heat exchanger E-51 resulting in release of ammonia fumes	Bounded by Chem # 27	Low
27	Leak from ammonia recovery column (V-52), overhead condenser (E-53), distillate tank (Tk-54) or associated equipment. Consequences assumed to be high without calculation due to high temperature and ammonia concentration in process solution.	27.1.3.1, 27.1.4.1, 27.1.5.1, 27.1.6.1, 27.9.1.1, 27.17.1.1	High
28	Spill of effluent waste solution containing 20 ppm ammonia covering entire EPB building floor. (Bounds spills from Tk-60, Evaporator, Tk-64, Tk-66 and Mixer)	30.1.2.1, 30.1.3.1, 30.1.4.1, 30.1.5.1, 30.1.8.1, 30.1.9.1, 30.1.10.1, 30.6.4.1, 30.9.3.1, 30.9.4.1, 30.17.2.1, 30.18.1.1, 35.3.1.1, 35.4.1.1, 35.7.1.2, 35.9.1.1, 35.10.1.1, 35.21.2.1, 35.21.3.1, 35.21.4.1, 35.21.5.1, 36.1.1.1, 36.1.2.1, 36.1.2.2, 36.1.3.1, 36.1.6.1, 36.1.7.1, 36.1.9.1, 36.3.1.1, 36.4.3.1, 36.6.2.1	Low
29	[redacted] gallon header leak from pH correction line containing dilute nitric acid to EPB floor	30.17.3.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
30	Leak from 60% nitric Acid Bulk Storage Tank to tank containment area resulting in release of acid fumes	49.1.2.1, 49.1.11.1	Intermediate
31	Leak from dilute acid bulk storage tank to tank containment area resulting in release of acid fumes	49.22.1.2	Low
32	Leak from ammonium hydroxide bulk storage tank to tank containment area resulting in release of ammonia fumes	27.9.1.2, 47.1.5.2, 47.3.1.1	High
33	Explosion of ammonium nitrate solution in systems containing significant amounts of ammonium nitrate solution (>1% weight) Systems include Tk-22, Tk-23, Centrifuge, Tk-38, Tk-40, Tk-41, cross flow filter, Tk-43, Ion Exchangers, Tk-47A and Tk-50	2.1.1.1, 3.1.7.1, 9.1.2.2, 17.1.7.1, 18.1.7.1, 20.1.6.1, 23.1.5.1, 25.1.1.1	High
34	Spill of ammonium nitrate solution	2.1.2.1, 3.1.2.1, 4.9.3.1, 9.1.1.1, 17.1.1.1, 18.1.1.1, 18.17.1.1, 20.1.1.1, 21.1.1.1, 23.3.1.1, 25.1.2.1	Low
35	Spill of sodium nitrate solution	30.1.2.1, 30.1.3.1, 30.1.4.1, 30.1.5.1, 30.1.8.1, 30.1.9.1, 30.1.10.1, 30.6.4.1, 30.9.3.1, 30.9.4.1, 30.17.2.1, 30.18.1.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
36	Spill of sodium hydroxide solution	48.1.1.1, 48.1.4.1, 48.1.5.1, 48.1.5.2, 48.3.1.1, 48.21.1.1	Low
37	Spill of boiler treatment chemical solutions	50.14.2.1	Low
38	Release of ammonia vapors from tank Tk-47B due to boiling during a fire in the tank gallery	FHA Fire Scenario 4	High
39	Release of ammonia vapors from tank Tk-23 due to boiling during fire on the OCB second floor	FHA Fire Scenario 5	Intermediate
40	Release of ammonia vapors due to damage to ARF equipment during a fire in the EPB	FHA Fire Scenario 6	High
41	Release of fumes due to loss of seal on overflow leg on tank Tk-38	9.1.6.1, 9.9.1.1, 9.13.1.1, 9.17.7.1, 9.17.3.1	Low
42	Release of fumes due to loss of seal on overflow leg on tank Tk-40	17.9.1.1	Low
43	Release of fumes due to loss of seal on overflow leg on tank Tk-43	20.1.2.1, 20.9.1.1	Low
44	Release of fumes due to loss of seal on overflow leg on tank Tk-47B	23.1.3.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
45	Release of fumes due to loss of seal on overflow leg on tank Tk-50	25.1.3.1, 25.11.1.1	Low
46	Release of fumes due to loss of seal on overflow leg on tank Tk-51	25.1.3.1, 25.11.1.1	Low
47	Spill from rupture of outside 60% nitric acid supply line that results in emptying the bulk storage tank to the ground	49.21.2.1	High
48	Spill from rupture of outside dilute nitric acid supply line that results in emptying the bulk storage tank to the ground	49.21.3.2	Intermediate
49	Spill from rupture of outside 23% aqua ammonia supply line that results in emptying the bulk storage tank to the ground	47.16.1.1	High
50	[redacted] gallon spill of dilute nitric acid from dilute acid supply header in the OCB	38.25.3.1	Low
51	Failure of Acid POG system and resultant leak of acid fumes to the room and/or to the environment.	8.1.2.1, 8.17.1.1, 8.17.2.1, 8.17.3.1, 8.17.4.2, 8.17.5.1, 8.19.2.1, 8.19.3.1, 8.19.4.1	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
52	Failure of Base POG system and resultant leak of ammonia fumes to the room and/or to the environment.	7.1.5.1, 7.19.2.1, 7.19.3.1, 7.19.4.1	Low
53	Failure of nuisance fume blower on the 60% nitric acid bulk tank during offloading operations.	49.1.6.1, 49.1.6.2	Low
54	Leak in vent system for the base tank header and resultant leak of ammonia fumes to the room	7.17.7.1	Low
55	NOx release due to addition of drum of enriched scrap material to natural dissolver	38.7.1.2	High
56	Outdoor [redacted] gallon leak of UNH solution from transfer line between UNB and OCB	1.17.1.1, 38.25.5.1	Low
57	Outdoor [redacted] gallon leak of liquid waste from ion exchanger effluent line to EPB	25.21.1.2	High
58	FHA general area fire scenarios in areas that do not contain equipment with potentially hazardous chemicals	FHA Scenario #1 FHA Scenario #2 FHA Scenario #3	Low

Chemical Evaluation No.	Bounding Accident Sequence Description	HAZOP Scenarios Bounded by Accident Sequence	Environmental Consequences
59	FHA explosion and torch fire scenarios related to hydrogen in the calciner off gas and related equipment	FHA Scenario #7 FHA Scenario #8 FHA Scenario #9 FHA Scenario #10	High
60	Uranium toxicity scenario related to radiological accident consequence analysis evaluations: OCB-RWC-12 OCB-RWC-15	38.7.1.2, 38.25.1.1	Low
61	Uranium toxicity scenario related to radiological accident consequence analysis evaluations: OCB-RWC-13 OCB-RWC-14 OCB-RWC-16 OCB-RWC-17 OCB-RWC-18	38.1.2.3, 38.1.11.1, 38.1.12.1, 38.1.20.3, 38.3.1.2, 38.3.2.2, 38.3.4.1, 38.3.5.1, 38.3.5.2, 38.7.3.1, 38.8.1.1, 38.8.2.2, 38.11.1.1, 38.17.1.2, 38.17.1.5, 38.25.8.1, 40.1.3.1, 40.1.6.1, 40.1.8.1, 40.1.13.1, 40.3.1.1, 40.3.2.1, 40.3.2.2, 40.3.2.3, 40.3.2.4, 40.3.3.1, 40.3.6.1, 40.3.7.1, 40.3.9.1, 40.3.10.1, 40.3.10.2, 40.3.11.1 40.3.13.1, 40.3.14.1, 40.6.2.3, 40.8.1.1, 40.8.2.1, 40.12.2.1, 40.14.1.1, 40.14.1.2, 40.15.1.1, 40.15.1.2, 40.25.1.2, 40.25.2.2, 40.25.4.1, 40.25.6.2, 40.25.9.1, 40.26.2.1, 43.1.1.1, 43.1.3.1, 43.1.4.2, 43.1.5.2, 43.1.6.1, 43.1.7.1, 43.1.8.1, 43.1.9.1, 43.1.10.1, 43.1.13.1, 43.1.14.1, 43.1.15.1, 43.3.1.1, 43.3.1.2, 43.3.2.1, 43.3.4.1, 43.5.3.1, 43.5.4.1, 43.6.1.2, 43.6.2.1, 43.17.1.1, 43.17.2.1, 43.18.1.1 UNB Node 14 (9.1.1, 9.1.2, 9.7.1, 9.8.1)	Low

Table 4-5
Environmental Safety Chemical Assumptions for Scenario Development

Parameter	Input Value	Units	Notes and Assumptions
Conversion Constants			
Weight of Water	8.34	lbs/gallon	
Gallons/ft3	7.48	gal/ft3	
Temperature			Or use a higher temperature value as appropriate (i.e., a reaction temperature of 60°C).
Max. Bulk Chemical Temp	86	F	
Max. Outdoor Temp.	95	F	
Indoor temp. (controlled env.)	70	F	
Relative Humidity	70	%	
Wind			
Outdoor Wind Speed	2.50	mph	
Indoor Wind Speed	0.05	mph	* Worst case stability class used
Stability Class	*		
Distance to nearest Controlled Area Boundary (outside controlled area)			
OCB to fence	81	ft	
OCB stack to fence	97	ft	
EPB to fence	55	ft	
EPB exhaust to fence	87	ft	
Bulk chemical storage to fence	46	ft	
Stack Information			
OCB Air Exhaust Stack			
Stack Temperature	70	F	
Stack Height	50	ft	
Stack Diameter	26	in	
Exhaust Rate	6900	ft^3/min	
Stack Exit Velocity	1871	ft/min	
Distance to Nearest Property Line	97	ft	

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 OCB/EPB process.

The accident scenarios for evaluation are provided on tables developed by a qualified ISA team during a Process Hazard Analysis, as specified in NFS-GH-55, "Integrated Safety 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. As per NFS-HS-A-68 "ISA Risk Assessment Program", the methods used for consequence evaluation are acceptable if the methods and calculations are consistent with the referenced approaches, they are scientifically correct as a reasonable estimate, and the use of generic assumptions and data is reasonably conservative for the types of accidents analyzed. 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 acute dose of 0.25 Sv (25 rem) or greater TEDE to any individual located outside the controlled area or an intake of 30 mg or greater of uranium in soluble form by any individual located outside the controlled area
- Intermediate Consequence - An acute dose of 0.05 Sv (5 rem) or greater TEDE to any individual located outside the controlled area or a 24-hour averaged release of radioactive material outside the restricted area in concentrations exceeding 5000 times the values in Table 2 of Appendix B to Part 20
- Low Consequence – Consequences that are not high or intermediate

The following is a generalized summary of the methodology utilized for the OCB/EPB Environmental Health Physics Consequence Analysis.

There are two primary means for radionuclides to migrate offsite. One of these is airborne that results in an exposure due to inhalation. The second method is by migration of liquid offsite, which could result in an exposure due to ingestion.

There is the potential for offsite releases due to the ingestion pathway for spills that occur outside. The largest spill analyzed was for [redacted] gallons and the resulting area of the spill would be approximately 1100 m^2. However, the area between the OCB, the UNB, and the site boundary is larger than the spill area. In addition, the slope of the runoff would be away from the boundary and towards the middle of the site. Therefore, it is not anticipated that there will be any consequences due to the ingestion pathway.

The inhalation pathway is discussed in the following section.

Inhalation Methodology

For uranium processing, the dose from the inhalation pathway will dominate the TEDE. A potential airborne release of radioactive material can occur in the OCB/EPB process if one of the following types of stress is imposed: thermal stress, explosive release (i.e., pressurized venting effects, shock effects, blast effects), free-fall spills and aerodynamic entrainment and resuspension.

The methodology utilized for consequence evaluation is consistent with guidance provided in NUREG/CR-6410, "Nuclear Fuel Cycle Facility Accident Analysis Handbook". 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, 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 modified to account for resuspension as shown in the following equation.

$$ST_{Air} = MAR * DR * LPF * [ARF * RF + (1\text{-}ARF) * ARR * t_D]$$

where:

ST_{Air}	=	Airborne Source Term (Ci or g)
MAR	=	Material at Risk (Ci or g)
DR	=	Damage Ratio
LPF	=	Leakpath Factor
ARF	=	Airborne Release Fraction
RF	=	Respirable Fraction
ARR	=	Airborne Release Rate (/hr), and
t_D	=	Resuspension Duration (hr)

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 1 for determining exposures to the public.

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 Airborne Release Rate (ARR) is used for mechanisms that continuously act to suspend radionuclides (e.g. aerodynamic entrainment/resuspension). The ARR 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 Dispersion Coefficients

The second step of the inhalation calculation methodology utilizes dispersion modeling to determine the concentration of the dispersed source term to the maximally exposed individual (MEI) outside the controlled area. The concentration of the dispersed source term is referred to as the dispersion coefficient and is reported in units of Ci/m^3 in air per Ci/s released or in simplified units of s/m^3. The following sections address the methodologies used to determine the dispersion coefficient for the public.

The atmospheric dispersion computer model HotSpot was utilized in the determination of the dispersion coefficient for the public. The HotSpot programs were created to provide health physics personnel with a tool for evaluating accidents involving radioactive material. There are 11 separate programs that make up the HotSpot modeling system ranging from general programs for downwind assessment following release of radioactive material to more specific programs dealing with the release of specific radionuclides. The program was run for all stability classes at a wind speed of 1 m/s to determine the most conservative stability class for each scenario.

Step 3 – Determine Dose Due to Inhalation

The third step of the methodology is to determine the dose to the MEI outside the controlled area due to the inhalation of the dispersed material. The following sections address the methodologies used to determine the dose due to inhalation for the MEI.

The TEDE for each radionuclide is calculated using the following equation. The exposure time is assumed equal to the release duration for calculating dose due to dispersed radiological material. This assumption results in a conservative estimate of the total dose.

$$D = ST_{Air} * \chi/Q * F_{Inh} * DCF$$

where:

D	=	Dose (rem)
ST_{Air}	=	Airborne Source Term (Ci)
χ/Q	=	Dispersion Coefficient (s/m^3)
F_{Inh}	=	Inhalation Rate (m^3/s)
DCF	=	Inhalation Dose Conversion Factor (rem/Ci)

The inhalation rate is assumed to be 3.33E-04 m^3/s in accordance with 10 CFR 20 Appendix B.

Step 4 – Determine Soluble Uranium Intake

The fourth step of the inhalation calculation methodology requires the determination of the soluble uranium intake for the MEI outside the controlled area. This step is performed only for accidents involving soluble uranium.

The public soluble uranium intake is determined using the following equation.

$$I_{U\text{-}Env} = ST_{Air} * \chi/Q * F_{Inh} * K$$

where:

I_U	=	Uranium Intake (mg)
STAir	=	Airborne Source Term (g)
χ/Q	=	Dispersion Coefficient (s/m3)
FInh	=	Inhalation Rate (m3/s)
K	=	Unit Conversion Factor (1E-3 m3-mg/ml-g)

The uranium intake for the MEI outside the controlled area was calculated for soluble uranium only (Class D and W) in accordance with 10 CFR 70.61(b)(3).

Step 5 –Concentration in Air Averaged Over 24-hour Period

Step 5 requires the calculation of the average concentration in air over a 24-hour period at the MEI outside the controlled area. This step utilizes the airborne source term and the dispersion coefficients determined in Steps 1 and 2. The dispersion coefficients are assumed to remain constant over a 24-hour period. The following equation is used.

$$Conc_{24} = \frac{MAR * DR * ARF * LPF * \chi/Q * K}{t_E}$$

where:

$Conc_{24}$	=	24-hour Average Concentration in Air (μCi/ml)
MAR	=	Material at Risk (Ci)
DR	=	Damage Ratio
ARF	=	Airborne Release Fraction
LPF	=	Leakpath Factor
χ/Q	=	Public Dispersion Coefficient (s/m^3)
t_E	=	Release Duration (86,400 s)
K	=	Unit Conversion Factor (1 $\mu Ci\text{-}m^3/Ci\text{-}ml$)

The concentrations are divided by the appropriate 10 CFR 20 Appendix B Table 2 value to determine the fraction of the Table 2 value in air. The severity consequence category is assigned based on the sum of fractions for all radionuclides. A sum-of-fractions greater than 5,000 would result in an "Intermediate" severity consequence category.

Bounding radiological environmental consequence scenarios were developed and the scenarios from the PHA were grouped under a specific bounding consequence evaluation. The grouping of the PHA scenarios and the results of the bounding consequences are provided in **Table 4-8.**

Table 4-8

Environmental Radiological Safety Consequence Analysis Summary

Evaluation Number	Scenario Evaluated	Calculation bounds Accident Sequence Number(s)	High, Intermediate or Low Consequence
OCB-ERC-1	Overall Vessel Failure of Centrifuge and Subsequent Spill [redacted] gallons low enriched solution/slurry Tank Gallery dilution volume (*UNB Node 13: 1.127.1)	1.1.1.2, 1.1.2.1, 1.1.2.2, 1.1.3.1, 1.1.4.1, 1.1.4.2, 1.3.1.1, 1.6.2.1, 1.6.3.1, 1.8.1.1, 1.8.2.1, 1.9.1.1, 1.9.2.1, 1.10.1.1, 1.14.1.1, 1.14.1.2, 1.14.1.3, 1.17.1.2, 1.17.1.5, 2.1.1.1, 2.1.2.1, 2.1.2.2, 2.3.1.2, 2.3.1.3, 2.3.2.2, 2.3.2.3, 2.4.2.2, 2.4.3.2, 2.6.3.1, 2.6.4.1, 2.8.1.1, 2.8.1.2, 2.9.1.1, 2.10.1.1, 2.14.1.1, 2.14.1.2, 2.14.1.3, 2.24.1.5, 2.24.1.6, 3.1.2.1, 3.1.2.2, 3.1.3.1, 3.1.4.2, 3.1.5.1, 3.1.5.2, 3.1.7.1, 3.3.1.1, 3.4.2.1, 3.6.1.1, 3.6.3.1, 3.8.2.1, 3.8.2.2, 3.9.1.1, 3.9.2.1, 3.10.1.1, 3.12.1.1, 3.14.1.1, 3.14.1.2, 3.14.1.3, 3.24.1.2, 3.24.1.5, 3.24.1.6, 4.1.1.2, 4.1.3.1, 4.1.4.1, 4.9.3.1, 4.20.1.1, *UNB Node 13: 1.127.1	Low
OCB-ERC-2	Aerodynamic Entrainment & Resuspension 225-gallons low enriched solution/slurry Tank Gallery dilution volume (1.11.1.1)	1.11.1.1, 2.11.1.1	Low
OCB-ERC-3	Overall Vessel Failure of IX ColumnsTank Gallery dilution volume (2.26.1.2)	2.26.1.2, 3.1.1.2, 3.6.2.2, 4.3.1.2	Low
OCB-ERC-4	Outdoor Release of LEUN	*UNB Node 13 (1.123.3, 1.123.2, 1.129.1, 1.130.1)	Low
OCB-ERC-5	Over pressurization of the dryer resulting in airborne release of [redacted] (183 l) of ADU liquid.	5.1.1.1, 5.1.2.1, 5.1.3.1, 5.1.4.1, 5.1.5.1, 5.1.6.1, 5.1.7.1, 5.1.8.1, 5.1.10.1, 5.3.2.1, 5.3.3.1, 5.3.4.1, 5.3.5.1, 5.12.2.1, 5.12.2.2, 5.18.3.2, 5.18.4.1, 6.18.1.17.1.1.1, 7.1.3.1, 7.1.3.11, 7.1.9.1, 7.1.11.1, 7.3.1.1, 7.3.2.1, 7.10.4.1, 7.10.4.2, 7.14.1.1, 7.14.2.1, 7.18.1.1, 7.18.1.11, 7.18.2.1, 7.18.2.2, 7.18.2.11, 7.19.2.3, 7.19.3.2, 7.19.3.3, 7.19.5.1, 7.19.5.11, 8.4.2.1, 8.10.1.1, 8.17.2.1, 8.17.3.1, 8.17.5.1, 9.1.1.1, 9.1.2.1, 9.1.3.1, 9.1.4.1, 9.1.6.1, 9.3.1.2, 9.4.1.2, 9.8.1.1, 9.9.1.1, 9.13.1.1, 9.17.1.1, 9.17.3.1, 9.17.4.1, 9.17.5.1, 9.17.5.2, 9.17.6.1, 9.17.6.2, 9.17.7.1, 9.17.8.1, 9.17.8.11	Low

OCB-ERC-6	Over pressurization of the blender resulting in airborne release of [redacted]kg (1250 l), UO_2 powder.	5.1.10.1, 5.1.11.1, 5.1.15.1, 5.1.5.1, 5.1.5.2, 5.1.7.1, 5.1.7.2, 5.1.8.1, 5.1.8.2, 5.3.1.1, 5.3.2.1, 5.3.2.2, 5.3.2.5, 5.3.3.1, 5.3.3.2, 5.3.4.1, 5.3.5.1, 5.12.1.1, 5.12.2.1, 5.18.3.2, 5.18.4.1, 6.1.3.1, 6.1.4.1, 6.1.5.1, 6.1.6.1, 6.1.7.1, 6.1.11.1, 6.1.12.1, 6.1.13.1, 6.1.14.1, 6.1.17.1, 6.1.18.1, 6.1.19.1, 6.1.20.1, 6.2.2.1, 6.2.3.1, 6.2.5.5, 6.2.6.1, 6.2.7.1, 6.2.9.1, 6.2.10.1, 6.4.3.1, 6.11.1.1, 6.12.2.1, 6.12.4.1, 6.12.5.1, 6.12.6.1, 6.18.2.1, 6.18.2.4, 6.18.3.1, 6.18.3.4, 6.18.4.1, 6.18.5.2, 6.18.6.1, 6.18.6.2, 6.18.7.1, 6.18.8.1, 6.20.2.1, 7.1.1.1, 7.1.1.2, 7.1.2.1, 7.1.3.1, 7.1.3.2, 7.1.3.5, 7.1.3.11, 7.1.9.1, 7.1.9.2, 7.1.9.5, 7.1.11.1, 7.1.11.2, 7.1.11.5, 7.1.11.10, 7.1.2.6, 7.1.3.10, 7.1.9.10, 7.3.1.1, 7.3.1.2, 7.3.1.5, 7.3.2.1, 7.3.2.2, 7.3.2.5, 7.3.1.10, 7.3.2.10, 7.10.4.1, 7.10.4.2, 7.14.1.1, 7.14.1.2, 7.14.1.5, 7.14.1.10, 7.14.2.10, 7.14.2.1, 7.14.2.2, 7.14.2.5, 7.17.11.1, 7.17.12.1, 7.17.4.2, 7.17.5.2, 7.17.6.2, 7.17.7.1, 7.17.8.2, 7.17.9.2, 7.18.1.1, 7.18.1.2, 7.18.1.5, 7.18.1.10, 7.18.2.1, 7.18.2.2, 7.18.2.5, 7.18.2.10, 7.19.2.2, 7.19.2.3, 7.19.2.4, 7.19.2.7, 7.19.2.12, 7.19.3.2, 7.19.3.3, 7.19.3.4, 7.19.3.7, 7.19.3.12, 7.19.5.1, 7.19.5.2, 7.19.5.5, 7.19.5.10, 7.19.5.11, 8.17.1.1, 8.19.1.2, 9.1.6.1, 9.3.1.2, 9.4.1.1, 9.9.1.1, 9.13.1.1, 9.17.1.1, 9.17.2.1, 9.17.2.4, 9.17.4.4, 9.17.6.1, 9.17.6.2, 9.17.6.4, 9.17.7.2, 9.17.8.1, 9.17.8.2, 9.17.8.5, 9.17.8.10, 9.17.8.12, 10.1.6.2, 10.1.9.1, 10.1.12.2, 10.1.13.2, 10.1.15.5, 10.3.3.2, 10.3.6.2, 10.3.7.2, 10.3.9.1, 10.11.1.1, 10.11.3.1, 10.17.1.1, 10.17.2.1, 10.17.3.1, 11.1.2.3, 11.1.3.2, 11.1.3.3, 11.1.4.1, 11.1.5.1, 11.3.2.2, 11.3.2.3, 11.3.2.4, 11.3.3.2, 11.3.3.3, 11.5.2.1, 11.10.1.1, 11.11.1.1, 11.17.1.1, 11.17..3.1, 11.9.1.1, 12.1.8.1, 12.1.9.1, 12.1.10.1, 12.1.11.1, 12.1.12.1, 12.1.13.1, 12.3.2.1, 12.3.3.1, 12.3.5.2, 12.3.8.1, 12.3.9.1, 12.16.1.2, 12.16.2.2, 12.17.1.1, 12.17.4.2, 12.17.5.2, 12.17.6.1, 12.19.2.2, 12.19.3.2, 12.19.3.3, 15.1.4.1, 15.17.1.1, 15.17.2.2, 16.1.10.1, 16.1.7.1, 16.3.1.1, 16.3.3.1, 16.3.4.1, 16.16.1.2, 16.17.2.2, 16.17.3.2, 16.18.1.1, 16.18.1.2	Low
OCB-ERC-7	High pressure causes overall containment failure of Tank 47A and it is spilled into tank gallery [redacted] gallons (23.9.1.3)	17.1.1.1, 17.1.2.1, 17.1.4.1, 17.1.7.1, 17.3.1.1, 17.4.1.1, 17.4.2.1, 17.4.3.1, 17.6.4.1, 17.9.1.1, 17.9.2.2, 17.10.1.1, 17.12.1.1, 17.12.2.1, 17.14.1.1, 17.14.3.1, 17.17.1.5, 17.17.1.6, 18.1.1.1, 18.1.2.1, 18.1.6.1, 18.1.7.1, 18.3.1.1, 18.4.4.1, 18.6.3.1, 18.8.1.1, 18.9.1.1, 18.12.2.1, 18.14.1.1, 18.14.1.2, 18.17.1.5, 20.1.1.1, 20.1.2.1, 20.1.3.1, 20.1.6.1, 20.3.1.1, 20.4.1.1, 20.4.2.1, 20.6.4.1, 20.8.1.1, 20.9.1.1, 20.9.1.3, 20.9.3.1, 20.9.3.3, 20.12.2.1, 20.14.1.1, 20.14.1.2, 20.17.1.5, 20.17.1.6, 21.1.1.1, 22.1.1.1, 22.1.3.1, 22.1.4.1, 22.3.1.1, 22.4.1.1, 22.6.3.1, 22.8.1.1, 22.8.2.1, 22.8.3.1, 22.9.1.1, 22.9.1.3, 22.17.1.5, 22.17.1.6, 23.1.3.1, 23.1.4.1, 23.1.5.1, 23.3.1.1, 23.4.1.1, 23.4.2.1, 23.9.1.1, 23.9.1.3, 23.14.1.1, 23.14.2.1, 23.17.1.5, 23.17.1.6	Low

OCB-ERC-8	Explosion IX Columns (21.7.1.1)	21.7.1.1, 21.18.1.2	Low
OCB-ERC-9	Overall containment failure of Tank 50 ([redacted]al) and subsequent spill of Tank 51 ([redacted]al). (25.1.4.1)	25.1.1.1, 25.1.2.1, 25.1.3.1, 25.1.4.1, 25.3.1.1, 25.4.1.1, 25.4.1.2, 25.4.2.1, 25.4.2.2, 25.4.3.1, 25.4.3.2, 25.9.1.1, 25.11.1.1, 25.14.1.1, 25.14.1.2, 25.19.1.1, 25.21.1.1, 25.21.1.2, 25.21.1.4, 27.1.1.1, 27.1.1.2, 27.3.1.1, 27.4.4.1, 27.6.3.1, 27.9.1.1, 27.9.1.3, 27.9.2.1, 27.9.2.3, 27.9.4.1, 27.10.1.1, 27.17.1.1, 27.17.1.4, 27.18.2.1, 27.18.3.2	Low
OCB-ERC-10	Over pressurization and complete failure of TK-64A. Spilling [redacted] gallons in the EPB. (30.9.3.1)	30.1.1.1, 30.1.2.1, 30.1.3.1, 30.1.4.1, 30.1.5.1, 30.1.6.1, 30.1.7.1, 30.1.8.1, 30.1.9.1, 30.1.10.1, 30.3.1.1, 30.3.2.1, 30.5.1.1, 30.6.3.1, 30.6.4.1, 30.8.1.1, 30.9.2.1, 30.8.2.9, 30.9.3.1, 30.9.4.1, 30.10.1.1, 30.17.2.1, 30.18.1.1, 35.1.3.1, 35.1.4.2, 35.3.1.1, 35.4.1.1, 35.7.1.2, 35.7.2.2, 35.8.1.2, 35.17.1.2, 35.20.1.3, 35.21.4.1, 35.21.5.1, 35.23.2.1, 36.1.1.2, 36.1.2.1, 36.1.2.3, 36.1.3.2, 36.1.4.2, 36.1.6.1, 36.1.7.1, 36.1.9.2, 36.3.1.1, 36.3.2.1, 36.4.1.1, 36.6.1.1, 36.17.1.1	Low
OCB-ERC-11	Overall containment failure of [redacted]allon (TK-70) natural uranyl nitrate in OCB (38.7.1.2)	38.7.1.2	Low
OCB-ERC-12	Spill [redacted]gallons (TK-70) hot natural uranyl nitrate solution in OCB (38.1.2.3)	38.1.2.3, 38.1.20.3, 38.3.1.2, 38.3.2.2, 38.7.3.1, 38.11.1.1, 38.17.1.2, 38.17.1.5	Low
OCB-ERC-13	Spill [redacted]gallon (TK-70 to TK-18 transfer) natural uranyl nitrate solution in UNB (38.1.11.1)	38.1.11.1, 38.1.12.1, 38.3.4.1, 38.8.1.1	Low
OCB-ERC-14	Spill of [redacted]g drum UO_3 powder in OCB (38.25.1.1)	38.25.1.1	Low
OCB-ERC-15	Outdoor spill of [redacted] gallons natural uranyl nitrate solution (38.3.5.1)	38.3.5.1, 38.3.5.2, 38.8.2.2 *UNB Node 14 (9.1.1, 9.1.2, 9.7.1, 9.8.1)	Low
OCB-ERC-16	Overall containment failure of V-73 resulting in the dispersion of 39.5 l of low enriched UO_2/U_3O_8 powder with 283 gU/l concentration (40.3.13.1).	40.3.13.1, 40.25.4.1	Low
OCB-ERC-17	Overall containment failure of V-76A resulting in a 15 gallon spill of 56.8 l of hot low enriched uranyl nitrate with 283 gU/l concentration (40.25.6.2)	40.1.8.1, 40.3.1.1, 40.3.2.4, 40.3.6.1, 40.3.7.1, 40.3.11.1, 40.6.2.3, 40.8.1.1, 40.8.2.1, 40.15.1.1, 40.15.1.2, 40.25.1.2, 40.25.2.2, 40.25.6.2, 40.25.9.1, 40.26.2.1, 43.1.1.1, 43.1.3.1, 43.1.4.2, 43.1.5.2, 43.1.8.1, 43.1.9.1, 43.1.10.1, 43.1.13.1, 43.1.14.1, 43.1.15.1, 43.3.2.1, 43.3.4.1, 43.5.3.1, 43.17.1.1, 43.17.2.1, 43.18.1.1	Low
OCB-ERC-6	Fire Scenario 1	Bounding 1400 KW Fire, First Floor Conversion Area	Low
OCB-ERC-6	Fire Scenario 2	Forklift Propane Torch Fire Exposure to Conversion Area	Low
OCB-ERC-18	Fire Scenario 3	OCB Loading Area Forklift Propane Fuel Fire	Low

OCB-ERC-1	Fire Scenario 4	OCB Tank Gallery Fire	Low
OCB-ERC-6	Fire Scenario 5	Conversion Area 2nd Floor Fire	Low
OCB-ERC-19	Fire Scenario 6	Effluent Building Fire	Low
NA	Explosion Scenario 1	Hydrogen Explosion in Calciner or Scrubber Off-Gas System	**High
NA	Explosion Scenario 2	Hydrogen Released into 2nd Floor Conversion Area	**High
NA	Explosion Scenario 3	Hydrogen Air-Dilution System Explosion	**High
NA	Explosion Scenario 4	Hydrogen Release and Torch Fire	**High

* *Items identified in UNB ISA Summary (21T-03-0664) as covered in OCB ISA Summary*
** Accident sequence assumed to lead to High Consequences

4.2.6 External Event Consequences

This section addresses potential OCB/EPB accidents initiated by natural phenomena or other significant hazards external to OCB/EPB 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

The BLEU Complex, which is on the NFS site, is located within the Southern Appalachian Tectonic Province, which extends from central Virginia to central Alabama and from the western edge of the Piedmont Province to the Cumberland Plateau Province. The Southern Tectonic Province has a moderate level of historical and recent earthquake activity. The NFS Site location is designated as Seismic Zone IIC in the 1999 Standard Building Code (SBC) 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 the NFS site.

A seismic analysis of the NFS Site determined there is no evidence of geologically recent fault displacements on the site that would be associated with capable faults in the surrounding region. For a 1000-year return period, the analysis yielded an effective peak horizontal ground acceleration rate of 0.06 gravity.

The OCB and EPB are designed and constructed in accordance with the Standard Building Code (1999).

Winds and Storms

Severe storm conditions are rare in the Erwin region, which is east of the typical area for tornado activity, south of most blizzard conditions, and too far inland to be affected by hurricane wind conditions. A maximum sustained wind of 50 mph in the regional area occurred in 1951, and a peak wind gust of 86 mph was reported in 1995. Wind data from the NFS Site collected over approximately the past three years indicate a maximum sustained wind of 29 mph.

The OCB and EPB are designed to withstand design basis winds per the 1999 SBC.

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. For Unicoi County, this data indicates a probability of 2 tornadoes per 100 years (1 E-2 per year over 186 sq. miles), or 2.5 E-6 per year for a tornado striking the NFS Controlled Area (0.047 sq. miles).

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, there are no credible accident scenarios that result in an intermediate or high consequence event as a result of a direct tornado strike on the OCB or EPB.

<u>Lightning</u>

A risk analysis for the NFS Site indicates a moderate to severe risk of facilities being damaged by lightning. The BLEU facility designs are reviewed for lightning risk and the appropriate protection is specified. The OCB and EPB building designs include lightning protection per the applicable building codes (specifically NFPA 780). There are no credible accident scenarios that result in an intermediate or high consequence event as a result of a lightning strike.

<u>Flood</u>

The Process Hazards Analysis found no credible accident scenario resulting from local area flooding because the BLEU Complex is well above the 100-year flood plain Base Flood Elevation. As shown in Figure 1-5, only the northern portion of the NFS site is within the 100-year flood plain of Martin Creek. The Town of Erwin participates in the National Flood Insurance Program (NFIP) created by Congress in 1968. Communities that participate in NFIP adopt and enforce flood plain management ordinances that provide flood loss reduction building standards for new and existing development. The lowest floor elevation for buildings that are located in the 100-year flood plain must be at least one (1) foot above the Base Flood Elevation. The OCB or EPB are not located in the 100-year flood plain, and the lowest floor elevation is fifteen (15) feet above the Base Flood Elevation, thus a large margin of safety exists. As such, there is no physically credible accident scenario that could result in a flood of the facility.

<u>CSX Transportation Railroad Yard</u>

The CSX Transportation 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 railroad tracks are approximately 100 feet from the OCB and EPB.

The bounding fire from a radiant heat exposure to the OCB or EPB would be an 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 to the OCB or EPB from a property damage standpoint.

LPG rail cars 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 DOT 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 rail car inventory is [redacted] gallons (approx. 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.

Based on an LPG tank car being parked in the CSX rail yard, with no loading or unloading operations, and based on the very strict tank car designs with no BLEVEs or vapor cloud explosions occurring over the last 21 years, the likelihood of having an LPG tank car BLEVE or explosion exposing the OCB or EPB is not considered a significant concern for BLEU Complex operations.

<u>Carolina Avenue</u>

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 site boundary security fencing installed next to the road, vehicles on Carolina Avenue would not be a significant concern for site operations.

<u>Local and Regional Airports</u>

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 primary east-west runway and a 4,447-foot 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 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 OCB or EPB operations.

Studsvik Processing Facility

The Studsvik Processing Facility (SPF), owned by Studsvik, LLC, is a state licensed low level radioactive waste processing facility located approximately 1,200 feet southwest of the NFS Controlled Area. 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: Co58, Co60, Mn54, Fe55, Cs134, Cs137, and N63.

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 by NFS, which may include the activation of its Emergency Response Organization, would be initiated in accordance with the NFS Emergency Plan (Chapter 8 of License SNM-124).

Bulk Chemical Storage

Bulk chemical storage supplies are listed in the table below. These chemicals were evaluated based on unmitigated 10 CFR 70.61 chemical exposure levels further defined in Section 7 of this report. The bulk chemical storage areas are currently protected by dikes sufficient to hold the stored volumes. The consequences of the scenarios and the designation of any IROFS is presented in process systems upset conditions in Section 4.2 and 4.3.

Leaks from bulk chemical storage tanks and associated pumps and supply lines located outside the process buildings were evaluated using the guidance of NUREG/CR-6410, Appendix B. Spills were postulated that resulted in the loss of the complete volume of the bulk storage tanks to their respective containment basins. In addition, line ruptures were postulated that resulted in leaks of potentially hazardous chemicals directly to the ground. Where the leaks occurred directly to the ground, the spill duration and pump capacity was considered sufficient to result in the complete emptying of the bulk storage tank contents to the ground.

Total Estimated Bulk Chemicals in OCB, EPB and Balance of Plant

Chemical	Amount On Site (lbs.)
Nitric Acid (100% basis)	[redacted]
Ammonium Hydroxide (as ammonia)	[redacted]
Sodium Hydroxide (100% basis)	[redacted]

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 OCB/EPB Risk Assessment are documented in the following tables.

Table 4-9
Criticality Safety Risk Index Table

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
OCB Precipitation					
Backflow-1	Process level control failure in TK-20 and High level in level control system fails and Pressure in TK-20 overcomes line elevation IE = -1	OPS-1(P) [-4] OPS-5(A) [-2]	Unc T = -1 Con T = -7	Unc = 3 Con = 1	9 3
Backflow-2	Process level control failure in TK-20 and TK-21 and High level in level control systems fail and Pressures in TK-20 and TK-21 overcome line elevations IE = -2	OPS-1(P) [-4] OPS-2(P) [-4] OPS-5(A) [-2]	Unc T = -2 Con T = -12	Unc = 1 Con = 1	9 3
Backflow-3	Process level control failure in TK-20 and Pressure in TK-20 exceeds pressure in DI water supply line IE = -1	OPS-1(P) [-4] OPS-5(A) [-2] OCB-4(A) [-2]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Backflow-4	Process level control failure in TK-22 and High-high level switch interlock fails and Pressure in TK-22 exceeds pressure in DNA or AH supply line IE = -1	OPS-3(P) [-4] OCB-5(A) or OCB-6(A) [-2]	Unc T = -1 Con T = -8	Unc = 3 Con = 1	9 3

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
Backflow-5	Process level control failure in TK-23 and High-high level switch interlock fails and Pressure in TK-23 exceeds pressure in DIW or AH supply line IE = -1	OPS-4(P) [-4] OCB-4(A) or OCB-6(A) [-2]	Unc T = -1 Con T = -7	Unc = 3 Con = 1	9 3
Backflow-6	See IROFS for Initiating Event Pressure in the uranium material feed line from TK-23 overcomes pressure in utility supply lines and ADU centrifuge becomes pressurized allowing flow across the failed three-way valve IE = -1	OPS-6(P) [-3] (IE Dur = 0) OPS-7(A) [-2]	Unc T = -1 Con T = -6	Unc = 3 Con = 1	9 3
Spill-5	Process level control failure in process tank and High-high level switch interlock fails IE = -1	OPS-1, 2, 3, or 4(P) [-4] OCB-1 [-2] OCB-2 [-2]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Spill-6	Structural Failure of Process Tank or Process Line IE=-1	OCB-1 [-2] OCB-2 or OCB-3 [-2]	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
OCB Dryer/Calciner					

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
Spill-6	Operator fails to ensure container is in place prior to activating system IE = -1	ODC-1(A) [-2] ODC-2(A) [-2]	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
OCB Uranium Recovery					
Backflow-1	High-level process control failure and Pressure Loss in Utility System and High-High level process control failure IE = -2	OUR-1(P) or OUR-2(P) or OUR-3(P) [-4] OCB -4(A) or OCB-5(A) or OCB-6(A) [-2]	Unc T = -2 Con T = -8	Unc = 3 Con = 1	9 3
Backflow-2	Valve Failure or Process Flow Failure and Pressure Loss in Utility System IE = -1	OCB -4(A) or OCB-5(A) or OCB-6(A) [-2] OUR-4 (A) or OUR-5(A) or OUR-6(A) [-2]	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
Spill-1	High-level process control failure and Operator fails to respond to high level alarm and correct situation and High-High level process control failure IE = -1	OUR-1(P) [-4] OCB-1 [-2] OCB-2 [-2]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Spill-2A	Structural Failure of SS Tank or Process Line IE = -2	OCB-1 [-2] OCB-2 [-2]	Unc T = -2 Con T = -6	Unc = 3 Con = 1	9 3
Spill-2B	Structural Failure of SS Tank or Process Line IE = -2	OCB-1 [-2] OCB-3 [-2]	Unc T = -2 Con T = -6	Unc = 3 Con = 1	9 3
OCB OXIDE BLENDING					
External water into blending system – ModCon area roof leak	Water on ModCon area roof IE = 0)	OBS-1 (P) (-3) --- OBS-5 (P) (-3)	Unc T = 0 Con T = -6	Unc = 3 Con = 1	9 3
External water into blending system – Liquid leak/spill inside OCB penetrates ModCon area	Liquid spill/leak inside OCB challenges ModCon area IE = -1	OBS-2 (P) (-2) --- OBS-5 (P) (-3)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	9 3
External water into blending system – Operator brings water into ModCon area	Operator brings water into the ModCon area (See IROFS for IE) Liquids spilled or spayed onto oxide blending system	OBS-3 (-2) (Dur = -1) --- OBS-5(P) (-3)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	9 3

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
External water into blending system – Water used to fight a large fire inside the ModCon area	Fire is ignited inside the ModCon area IE = -1 Large fire resulting from IE and failure of OBS-3, degrades oxide blending system. Therefore, OBS-2 is not credited for protection	OBS-6 (-2) --- OBS-4 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
External water into blending system – Liquid leak/spill inside OCB penetrates vessel V-33 or V-34 outside of ModCon area	Liquid source inside OCB sprays against vessel V-33 or V-34 IE = -1	OBS-5(P) (-3) --- OBS-8(A) (-2)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	9 3
Wet powder is discharged from calciner	Wet powder is discharged from calciner V-32 IE = -1	OBS-7 (A) (-2) --- OBS-8 (A) (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
Inadvertent transfer of wet powder into unfavorable geometry vessel	Wet powder inside vessel V-33/V-34 IE = -1	OBS-9 (-2) --- OBS-10 (A) (-2) --- OBS-7 (A) (-2) --- OBS-8 (A) (-2)	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Water enters blending system through compressed air system – internally supplied air	Water enters compressed air system supply lines IE = -1 Powder inside V-34 is not oxidized to U_3O_8	OBS-11 (A) (-2) --- OBS-8 (A) (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
Water enters blending system through compressed air system – externally supplied air	Water enters compressed air system supply lines IE = -1	OBS-11 (A) (-2) --- OBS-5 (P) (-3)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	9 3

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
Too much dry powder in blender results in >15.8 kg water	Operator loads more than [redacted] of oxide into blender (See IROFS for IE) Virtually all the moisture in the powder evaporates, recondenses, and enters the powder bed to form a critical configuration EE = -1	OBS-12 (-2) (Dur = 0) --- OBS-13 (-2)	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
Dry oxide powder spills from the oxide blending system	Greater than [redacted] of oxide powder spills from system (See IROFS for IE)	OBS-14 (A) (-2) (Dur = -1) --- See scenarios 1.1a, 1.1b, 1.1c, 1.1d, 1.4a, and 1.4b for determination of index value (-3)	Unc T = 0 Con T = -6	Unc = 3 Con = 1	9 3
Wet oxide powder spills from the oxide blending system	Wet powder is discharged from calciner V-32 IE = -1	OBS-9 (-2) --- OBS-14 (A) (-2) --- OBS-15 (-1)	Unc T = -1 Con T = -6	Unc = 3 Con = 1	9 3
OCB Oxide Dissolution					
Backflow of Uranium Bearing Solutions to Process Supply Systems	Loss of Process Control Within the LEU Dissolution Tank IE = -1	ODS-1 (P) or ODS-2(P) [-4] --- OCB-4 (A) [-2]	Unc T = -2 Con T = -8	Unc = 3 Con = 1	9 3
Backflow of Uranium Bearing Solutions to Process Supply Systems	Loss of Process Control Within the LEU Dissolution Tank IE = -1	ODS-1 (P) or ODS-2(P) [-4] --- OCB-5 (A) [-2]	Unc T = -2 Con T = -8	Unc = 3 Con = 1	9 3

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
LEU Solution Leak Into Heat Exchanger	Primary Heat Exchanger Leaks (LEU to Cooling Water Side) IE = -1	ODS-3 (P) [-3] ODS-4 (A) [-2]	Unc T = -1 Con T = -6	Unc = 3 Con = 1	9 3
Backflow of LEU Solution Through Ventilation System to Natural Dissolution	Loss of Process Control Within the LEU Dissolution Tank IE = -1	ODS-1 (P) or ODS-2(P) [-4] ODS-7 (P) [-4]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
LEU Powder Added to Natural Dissolver	LEU Powder Placed in Nat. U Feed Enclosure IE = -1	ODS-5 (A) [-2] ODS-6(A) [-2]	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
OCB Ventilation					
Chronic Accumulation of Moderated Uranium in Unfavorable Geometry Ductwork	A chronic accumulation of uranium forms in the unfavorable geometry ventilation ductwork IE = 0	OVS-2 [-2] OVS-3 [P] [-4]	Unc T = 0 Con T = -6	Unc = 3 Con = 1	9 3
Acute Accumulation of Moderated Uranium in Unfavorable Geometry Ductwork	An acute accumulation of uranium forms in the unfavorable geometry ventilation ductwork. IE = -1	OVS-1 [P] [-3] OVS-3 [P] [-4]	Unc T = 0 Con T = -8	Unc = 3 Con = 1	9 3
Solution Enters the Unfavorable Geometry Ductwork From Scrubber V-38A	Scrubber V-38A overflows IE = -1	OVS-9 (P) [-4] OVS-3 (P) [-4]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Solution Enters the Unfavorable Geometry Ductwork From the Base POG	Equipment vented by the Base POG (TK-22, TK-23, TK-38, TK-40, TK-41, TK-43, TK-45U, or TK-47B) overflows IE = -2	OVS-3 (P) [-4] OVS-9 (P) [-4]	Unc T = -2 Con T = -10	Unc = 3 Con = 1	9 3

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
Solution Enters the Unfavorable Geometry Ductwork From Scrubber V-38B	Scrubber V-38B overflows IE = -1	OVS-3 (P) [-4] OVS-10 (P) [-4]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Solution Enters the Unfavorable Geometry Ductwork From Dissolver TK-70	Dissolver TK-70 overflows or condensation from E-70C fails to drain to TK-70 IE = -2	OVS-3 (P) [-4] OVS-10 (P) [-4]	Unc T = -2 Con T = -10	Unc = 3 Con = 1	9 3
Backflow of Uranium into Unfavorable Geometry Systems – Deionized Water – TK-78	TK-78 overflows and DIW system loses supply pressure IE=-2	OCB-4 (A) [-2] OVS-4 (P) [-4]	Unc T = -2 Con T = -8	Unc = 3 Con = 1	9 3
Backflow of Uranium into Unfavorable Geometry Systems – Deionized Water – V-38A	V-38A overflows and DIW system loses supply pressure IE=-1	OVS-5 (P) [-4] OVS-6 (P) [-4]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Backflow of Uranium into Unfavorable Geometry Systems – Deionized Water – V-38B	V-38B overflows, and DIW system loses supply pressure IE=-1	OVS-5 (P) [-4] OVS-11 (P) [-4]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Backflow of Uranium into Unfavorable Geometry Systems – Compressed Air – V-77	V-77 overflows, and CA system loses supply pressure IE=-1	OVS-7 (P) [-4] OVS-9 (P) [-4]	Unc T = -1 Con T = -9	Unc = 3 Con = 1	9 3
Backflow of Uranium into Unfavorable Geometry Systems – Natural Uranium Dissolver – TK-70	Solution moves enriched uranium in the ductwork to the natural uranium dissolver IE=-2	OVS-3 (P) [-4] OVS-10 (P) [-4]	Unc T = -2 Con T = -10	Unc = 3 Con = 1	9 3

Accident Sequence	Initiating Event (IE) or Enabling Event (EE) Sequence	IROFS Effectiveness of Protection	Likelihood Index T Uncontrolled/ Controlled	Likelihood Category	Risk Index
EPB Ammonia Recovery/Liquid Waste Systems					
Excess Uranium-1	Valve misalignment or Valve failure or Loss of pH control on Ion Exchange System or Excess feed rate to Ion Exchange System or Contaminants compete with Ion Exchange Resin or Wrong resin in Ion Exchange System or Cross Flow Filter failure IE = -1	EAL-1 [-2] EAL-2 [-2]	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3
Excess Uranium-2	Valve misalignment or Valve failure or Loss of pH control on Ion Exchange System or Excess feed rate to Ion Exchange System or Contaminants compete with Ion Exchange Resin or Wrong resin in Ion Exchange System or Cross Flow Filter failure IE = -1	EAL-3 [-2] EAL-4 [-2]	Unc T = -1 Con T = -5	Unc = 3 Con = 1	9 3

Table 4-10
Chemical Safety Risk Assessment (Worker)

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS₁ and IROFS failure	Mitigative/ Preventive IROFS₂ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
2.1.1.1	P-22 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-22 high casing temperature due to deadhead configuration	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Instrumentation failure	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Line plugging	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
2.14.1.3	Overflow of base vent header tanks due to TK-22 overflow into the vent header	Level control loop closes control valve at upper end of operating band, initiates deviation alarm if level goes outside of normal operating band, and initiates a level alarm at high level setpoint	Inlet flow exceeds outlet flow forcing liquid into vent lines	-1	Passive Engineered Control -- Overflow line	Active Engineered Control -- Tank high level switch interlock closes tank inlet isolation valves	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Overflow plugged		Overflow plugged		Overflow plugged	Tank high level switch interlock closes tank inlet isolation valves	-3 dur=-2	-2	U C	-3 -7	2 1	3 3	6 3
IROFS failure	Failure of tank high level switch interlock to close tank inlet isolation valves		Instrumentation failure		Failure of tank high level switch interlock to close tank inlet isolation valves	Overflow line	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
2.24.1.1	Leak from 23% ammonia header resulting in release of chemical fumes		Line rupture	-1	Passive Engineered Control -- Materials of construction compatible with process fluids	Administrative Control -- Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
3.1.7.1	P-23 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.		-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
3.14.1.3	Overflow of base vent header tanks due to TK-23 overflow into the vent header	Level control loop closes control valve at upper end of operating band, initiates deviation alarm if level goes outside of normal operating band, and initiates a level alarm at high level setpoint	Inlet flow exceeds outlet flow forcing liquid into vent lines	-1	Passive Engineered Control – Overflow line	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Overflow plugged		Overflow plugged		Overflow plugged	Tank high level switch interlock closes tank inlet isolation valves	-3 dur=-2	-2	U C	-3 -7	2 1	3 3	6 3
IROFS failure	Failure of tank high level switch interlock to close tank inlet isolation valves		Instrumentation failure		Failure of tank high level switch interlock to close tank inlet isolation valves	Overflow line	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
5.1.5.2	High moisture content in the feed causing over-pressurization of the calciner resulting in release of off-gas to room	Dryer operates at elevated temperatures to reduce the moisture content of the ADU solids before sending to calciner; downstream filter differential pressure indicators provide indication of off-normal condition; Instruments analyze calciner discharge moisture content	Pluggage in dryer off-gas line	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Pluggage in dryer off-gas filter	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
5.3.1.1	High moisture content in the feed causing over-pressurization of the calciner resulting in release of off-gas to room	Dryer operates at elevated temperatures to reduce the moisture content of the ADU solids before sending to calciner; Instruments analyze calciner discharge moisture content	Residence time in dryer too short	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
5.12.1.1	High moisture content in the feed causing over-pressurization of the calciner resulting release of off-gas to room	Off-normal condition of heaters will be indicated on CCS; downstream filter differential pressure indicators provide indication of off-normal condition; Instruments analyze calciner discharge moisture content	Loss of dryer heater	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Dryer heater setpoint too low	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.1.3.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Procedures and training: operator responds to off-normal condition of calciner tube rotation as indicated by CCS	Calciner tube rotation failure	0	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	0 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.1.5.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Off-normal condition at rotary valve indicated at CCS Instruments analyze calciner discharge moisture content	Rotary valve on calciner discharge (FV-32D) fails	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Rotary valve on calciner discharge (FV-32D) plugs	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
6.1.6.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Instruments analyze calciner discharge moisture content	Rear breech of calciner plugs	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.1.7.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Downstream filter differential pressure indicators provide indication of off-normal condition Instruments analyze calciner discharge moisture content	Powder plugs off-gas line	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.1.11.1	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Blinding of primary filter, V-32F	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.1.12.1	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Blinding of back filter, V-32B	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.1.13.1	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Failure of filter rotary valve	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Bridging at discharge of primary filter	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
6.2.2.1	Calciner over-pressurization resulting in release of off-gas to room	Operator sets N2 flow at rotameter Downstream blowers maintain a negative pressure within the calciner pulling off-gases from the calciner and exhausting from stack	High N2 flow through calciner	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.2.3.1	Plugging that restricts off gas flow causing calciner pressurization and causing release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Excessive product from add-back system during normal operations	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.2.4.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Downstream filter differential pressure indicators provide indication of off-normal condition Instruments analyze calciner discharge moisture content	Excessive ADU inlet flow to calciner	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.2.5.5	Calciner over-pressurization resulting in release of off-gas to room	Operator sets H2 flow at rotameter Downstream blowers maintain a negative pressure within the calciner pulling off-gases from the calciner and exhausting from stack	High H2 flow through calciner	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
6.12.2.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Off-normal condition of off-gas heat trace should display at CCS Instruments analyze calciner discharge moisture content Downstream filter differential pressure indicators provide indication of off-normal condition	Failure of off-gas heat trace resulting in wet powder	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
7.1.3.5	Calciner over-pressurization resulting in release of off-gas to room	Upstream filter differential pressure indicators provide indication of off-normal condition Off-normal condition on off-gas blower indicated at CCS Instruments analyze calciner discharge moisture content	Off-gas blower (B-38B) fails	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
7.17.9.2	Personnel exposure to ammonia fumes/release of off-gas to room		Leak in V-38B bottoms line	-2	Passive Engineered Control – Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-2 -7	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
7.18.2.2	High moisture content in the feed to the calciner, leading to calciner over-pressurization resulting in release of off-gas to room	Materials of construction Maintenance procedures and training	Leak of cooling water into calciner off-gas line	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS₁ and IROFS failure	Mitigative/ Preventive IROFS₂ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
7.18.2.5	Calciner over-pressurization resulting in release of off-gas to room	Materials of construction Maintenance procedures and training	Leak of cooling water into calciner off-gas line	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
7.19.3.4	High moisture content in the feed to the calciner, leading to calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Packing support plate fails resulting in plugged column	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
7.19.3.7	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Packing support plate fails resulting in plugged column	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
9.1.1.1	Overflow of TK-38 resulting in release of chemical fumes	Procedures and training Level and flow indication provide indication of off-normal condition	Improper valve lineup HV-38D closed	-1	Enhanced Administrative Control – Tank high level alarm on CCS	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level alarm on CCS		Instrumentation failure		Failure of tank high level alarm on CCS	Tank high level switch interlock closes tank inlet isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch interlock to close tank inlet isolation valves		Instrumentation failure		Failure of tank high level switch interlock to close tank inlet isolation valves	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
9.1.2.2	P-38 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-38 high casing temperature due to deadhead configuration	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
9.8.1.1	Condensate tank drain valve inadvertently left open resulting in chemical fumes to room	Level and flow indication provide indication of off-normal condition	Human error	-1	Passive Engineered Control -- Cap (valve discharge is capped when not in use)	Administrative Control – Operating procedures and training	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Valve discharge is not capped		Human error		Valve discharge is not capped	Operating procedures and training	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Improper valve operation		Human error		Improper valve operation	Cap (valve discharge is capped when not in use)	-2 dur= -1	-3	U C	-1 -6	3 1	3 3	9 3
9.17.4.1	Release of chemical fumes to room		Leak/rupture in base scrubber (V-38B) drain line	-1	Passive Engineered Control -- Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
9.17.5.1	Release of chemical fumes to room	Flow and pressure indicators provide indication of off-normal condition	Liquid leak/rupture in TK-38 associated piping	-1	Passive Engineered Control -- Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
9.17.6.1	Release of chemical fumes to room	Level, flow, and pressure indicators provide indication of off-normal condition	Leak/rupture in TK-38	-1	Passive Engineered Control – Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
17.1.1.1	Overflow from TK-40 resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged vent line	-2	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch interlock to isolate feed to tank		Instrumentation failure		Failure of tank high level switch interlock to isolate feed to tank	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock isolates feed to tank	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
17.1.3.1	Overflow from TK-40 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged overflow line	-1	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
			P-40 failure	-1	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			P-40 shut off	-1	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			TK-40 discharge line valves shut	-1	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch interlock to isolate feed to tank		Instrumentation failure		Failure of tank high level switch interlock to isolate feed to tank	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock isolates feed to tank	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
17.1.7.1	P-40 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-40 high casing temperature due to deadhead configuration	-1	Passive Engineered Control – Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
17.3.1.1	Overflow from TK-40 resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Excessive inlet flow	-1	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch interlock to isolate feed to tank		Instrumentation failure		Failure of tank high level switch interlock to isolate feed to tank	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock isolates feed to tank	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
17.8.2.1	Overflow from TK-40 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged overflow line	-1	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch interlock to isolate feed to tank		Instrumentation failure		Failure of tank high level switch interlock to isolate feed to tank	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock isolates feed to tank	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
17.14.2.1	Overflow from TK-40 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged discharge line	-1	Active Engineered Control – Tank high level switch interlock isolates feed to tank	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS₁ and IROFS failure	Mitigative/ Preventive IROFS₂ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of tank high level switch interlock to isolate feed to tank		Instrumentation failure		Failure of tank high level switch interlock to isolate feed to tank	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock isolates feed to tank	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
17.17.1.1	Leak in TK-40 resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control – Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
18.1.7.1	P-41 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-41 high casing temperature due to deadhead configuration	-1	Passive Engineered Control – Pump recirculation line	Active Engineered Control – Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
18.14.2.1	Overflow from TK-41 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Multiple inlet lines open	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
18.14.2.2	Overflow from TK-41 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged discharge line	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
20.1.1.1	Overflow from TK-43 resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged discharge filter	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
20.1.4.1	Overflow from TK-43 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged overflow line	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
20.1.6.1	P-43 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-43 high casing temperature due to deadhead configuration	-1	Passive Engineered Control – Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS₁ and IROFS failure	Mitigative/ Preventive IROFS₂ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U, C	-2 -4	3 1	3 3	9 3
20.3.1.1	Overflow from TK-43 resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	High inlet flow	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U, C	-1 -5	3 1	3 3	9 3
			Multiple inlet lines open	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U, C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U, C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U, C	-2 -4	3 1	3 3	9 3
20.8.2.1	Overflow from TK-43 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged overflow line	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U, C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U, C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U, C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
20.14.2.1	Overflow from TK-43 into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged discharge line	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
20.17.1.1	Leak in TK-43 resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
21.1.1.1.A	Leak of IX column V-45A resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Mechanical failure	-1	Passive Engineered Control – Materials of construction	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
21.1.1.1.B	Leak of IX column V-45B resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Mechanical failure	-1	Passive Engineered Control – Materials of construction	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
21.1.1.1.C	Leak of IX column V-45C resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Mechanical failure	-1	Passive Engineered Control – Materials of construction	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
23.1.5.1	P-47B explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-47B high casing temperature due to deadhead configuration	-1	Passive Engineered Control - Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
23.3.1.1	Overflow from TK-47B resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	Excessive inlet flow	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valve		Instrumentation failure		Failure of tank high level switch to close feed isolation valve	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valve	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
23.8.2.1	Overflow from TK-47B into vent system resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged overflow line	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS₁ and IROFS failure	Mitigative/ Preventive IROFS₂ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of tank high level switch to close feed isolation valves		Instrumentation failure		Failure of tank high level switch to close feed isolation valves	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
23.14.1.1	Overflow from TK-47B into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	Plugged discharge line	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Plugged discharge filter, F-47B	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valves		Instrumentation failure		Failure of tank high level switch to close feed isolation valves	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
23.14.2.1	Overflow from TK-47B into other tanks through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	High inlet flow	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Multiple inlet lines open	-1	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valves		Instrumentation failure		Failure of tank high level switch to close feed isolation valves	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
23.17.1.1	Leak in TK-47B resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
25.1.1.1	P-50 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-50 high casing temperature due to deadhead configuration	-1	Passive Engineered Control - Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
25.21.1.2	Leak in liquid waste piping outside of building resulting in offsite release of acid fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
27.1.3.1	Overflow from TK-54 into other vessels through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	Loss of TK-54 discharge flow	0	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U C	0 -4	3 1	3 3	9 3
IROFS failure	Failure of tank high level switch to close feed isolation valves		Instrumentation failure		Failure of tank high level switch to close feed isolation valves	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
27.1.4.1	Over-pressurization of stripper columnV-52	E-53 cooling water inlet and outlet lines have temperature indication.	Loss of cooling water to overhead condenser E-53	-1	Active Engineered Control – Steam supply shut off on stripper column high pressure	Enhanced Administrative Control – Stripper column high pressure alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of stripper high pressure steam supply shutoff interlock		Instrumentation failure		Failure of stripper high pressure steam supply shutoff interlock	Stripper column high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on stripper column high pressure		Instrumentation failure		Failure of CCS to alarm on stripper column high pressure	Steam supply shut off on stripper high pressure	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
27.1.5.1	Inadequate scrubbing in V-59 with release of ammonia vapors to the environment	Operator routinely monitors flow and ammonia concentration indications. Procedures address corrective actions to prevent exhaust stack high ammonia concentration conditions.	Inadequate DIW flow to V-59	-1	Enhanced Administrative Control – DIW to V-59 low flow alarm on CCS	Enhanced Administrative Control – Exhaust stack high ammonia concentration alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of DIW to V-59 low flow alarm on CCS		Instrumentation failure		Failure of DIW to V-59 low flow alarm on CCS	Exhaust stack high ammonia concentration alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of exhaust stack high ammonia concentration alarm on CCS		Instrumentation failure		Failure of exhaust stack high ammonia concentration alarm on CCS	DIW to V-59 low flow alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
27.1.6.1	Increased liquid level in V-59 resulting in release of ammonia vapors to the environment	Operator training on proper operation of equipment.	Ammonia recovery scrubber liquid discharge valve closed	-1	Administrative Control – Operating procedures and training prevent improper valve operation	Administrative Control – Tamper seal placed on scrubber discharge valve	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of operating procedures and training to prevent improper valve operation				Failure of operating procedures and training to prevent improper valve operation	Tamper seal placed on scrubber discharge valve	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure to install tamper seal				Failure to install tamper seal	Operating procedures and training prevent improper valve operation	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
27.9.1.1	Over-pressurization of TK-54	Overpressurization failure prevented by vent path through E-53 to V-52 relief valve.	Failure of ammonia scrubber vent pressure control valve PCV-542	-2	Passive Engineered Control - Pressure vent path through V-59	Enhanced Administrative Control – Tank/header high pressure alarm on CCS	-3	-2	U C	-2 -7	3 1	3 3	9 3
IROFS failure	Vent plugged		Mechanical failure		Vent plugged	Tank/header high pressure alarm on CCS	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of high tank/header pressure alarm on CCS		Instrumentation failure		Failure of high tank/header pressure alarm on CCS	Pressure vent path through V-59	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
27.9.1.2	Over-pressurization of TK-AH	Overpressurization failure prevented by tank relief valve	Failure of ammonia scrubber vent pressure control valve PCV-542	-2	Passive Engineered Control - TK-AH vent path through V-59	Enhanced Administrative Control – Tank/header high pressure alarm on CCS	-3	-2	U C	-2 -7	3 1	3 3	9 3
IROFS failure	Vent plugged		Mechanical failure		Vent plugged	Tank/header high pressure alarm on CCS	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure of high tank/header pressure alarm on CCS		Instrumentation failure		Failure of tank/header high pressure alarm on CCS	Pressure vent path through V-59	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
27.17.1.1	Leak in V-52 resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
38.7.1.2	Overflow from TK-70 resulting in release of chemical fumes and soluble uranium toxicity hazards	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	Violent reaction due to inadvertent addition of drum of enriched scrap material	-2	Administrative Control - Administrative controls on NUN dissolver feed material	Active Engineered Control: Enrichment monitor disables overhead crane operation to prevent transporting enriched material to the NUN dissolver hopper.	-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of enrichment monitor to disable overhead crane		Instrumentation failure		Enrichment monitor fails to disable overhead crane operation to prevent transporting enriched material to the NUN dissolver hopper.	Administrative controls on NUN dissolver feed material	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Loss of feed material control		Human error		Loss of feed material control	Enrichment monitor disables overhead crane operation to prevent transporting enriched material to the NUN dissolver hopper.	-2 dur= -2	-2	U C	-2 -6	3 1	3 3	9 3
40.3.1.1	Overflow of TK-76A and subsequent overflow to TK-76B and TK-76R with release of acid and chemical fumes into the room	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	High nitric acid flow into TK-76A	-1	Active Engineered Control – Dissolver high level switch interlock closes feed isolation valves and de-energizes auger	Enhanced Administrative Control – Dissolver high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of dissolver high level switch interlock to close feed isolation valves and de-energize auger		Instrumentation failure		Failure of dissolver high level switch interlock to close feed isolation valves and de-energize auger	Dissolver high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of dissolver high level alarm on CCS		Instrumentation failure		Failure of dissolver high level alarm on CCS	Tank high level switch interlock closes feed isolation valves and de-energizes auger	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
40.3.2.4	Plugging in dissolver lines resulting in release of acid and chemical fumes into the room through TK-76R overflow line	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	High powder feed rate	-1	Active Engineered Control – Dissolver high level switch interlock closes feed isolation valves and de-energizes auger	Enhanced Administrative Control – Dissolver high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of dissolver high level switch interlock to close feed isolation valves and de-energize auger		Instrumentation failure		Failure of dissolver high level switch interlock to close feed isolation valves and de-energize auger	Dissolver high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of dissolver high level alarm on CCS		Instrumentation failure		Failure of dissolver high level alarm on CCS	Tank high level switch interlock closes feed isolation valves and de-energizes auger	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
40.6.2.3.A	Leak in TK-76A resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
40.6.2.3.B	Leak in TK-76B resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
40.6.2.3.C	Leak in TK-76R resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
40.11.1.1.A	Damage to equipment downstream of TK-76A resulting in release of chemical fumes	Operator routinely monitors tank temperature indication. Procedures address corrective actions to tank overheating conditions.	Failure of TK-76A heater controller in energized state	-1	Enhanced Administrative Control – Tank TK-76A high temperature alarm on CCS	Enhanced Administrative Control – Tank TK-76B high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank TK-76A high temperature alarm on CCS		Instrumentation failure		Failure of tank TK-76A high temperature alarm on CCS	Tank TK-76B high temperature alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of tank TK-76B high temperature alarm on CCS		Instrumentation failure		Failure of tank TK-76B high temperature alarm on CCS	Tank TK-76A high temperature alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
40.11.1.1.B	Damage to equipment downstream of TK-76B resulting in release of chemical fumes	Operator routinely monitors tank temperature indication. Procedures address corrective actions to tank overheating conditions.	Failure of TK-76B heater controller in energized state	-1	Enhanced Administrative Control – Tank TK-76B high temperature alarm on CCS	Enhanced Administrative Control – Tank TK-76R high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of tank TK-76B high temperature alarm on CCS		Instrumentation failure		Failure of tank TK-76B high temperature alarm on CCS	Tank TK-76R high temperature alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of tank TK-76R high temperature alarm on CCS		Instrumentation failure		Failure of tank TK-76R high temperature alarm on CCS	Tank TK-76B high temperature alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS₁ and IROFS failure	Mitigative/ Preventive IROFS₂ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
43.1.3.1	High liquid level in V-77 plugging dissolver offgas vent inlet resulting in release of chemical fumes through tank overflow lines	Operator routinely monitors scrubber level indication. Procedures address corrective actions to prevent high level conditions.	V-77 bottoms line isolated	-2	Active Engineered Control – V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	Enhanced Administrative Control – V-77 high level alarm on CCS	-2	-2	U C	-2 -6	3 1	3 3	9 3
			P-77 fails to operate to maintain proper level in V-77	-1	Active Engineered Control – V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	Enhanced Administrative Control – V-77 high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of V-77 vent header high pressure switch interlock to close dissolver feed isolation valves		Instrumentation failure		Failure of V-77 vent header high pressure switch interlock to close dissolver feed isolation valves	V-77 high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of V-77 high level alarm on CCS		Instrumentation failure		Failure of V-77 high level alarm on CCS	V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
43.1.8.1	Pressurization of dissolver offgas system resulting in release of chemical fumes through tank overflow lines	Vacuum in scrubber vent line provided by blower in acid POG vent system.	B-77 failure	-1	Active Engineered Control – V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	Enhanced Administrative Control – V-77 scrubber differential pressure high/low alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Dissolver offgas blower discharge line plugged	-1	Active Engineered Control – V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	Enhanced Administrative Control – V-77 scrubber differential pressure high/low alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of V-77 vent header high pressure switch interlock to close dissolver feed isolation valves		Instrumentation failure		Failure of V-77 vent header high pressure switch interlock to close dissolver feed isolation valves	V-77 scrubber differential pressure high/low alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of V-77 scrubber differential pressure high/low alarm on CCS		Instrumentation failure		Failure of V-77 scrubber differential pressure high/low alarm on CCS	V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
43.5.3.1	Pressurization of dissolver offgas system resulting in release of chemical fumes through tank overflow lines	Vacuum in scrubber vent line provided by blower in acid POG vent system.	Upper bed packing support plate fails	-1	Active Engineered Control – V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	Enhanced Administrative Control – V-77 scrubber differential pressure high/low alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of V-77 vent header high pressure switch interlock to close dissolver feed isolation valves		Instrumentation failure		Failure of V-77 vent header high pressure switch interlock to close dissolver feed isolation valves	V-77 scrubber differential pressure high/low alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of V-77 scrubber differential pressure high/low alarm on CCS		Instrumentation failure		Failure of V-77 scrubber differential pressure high/low alarm on CCS	V-77 high vent header pressure switch interlock closes dissolver feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
43.17.2.1	Leak in dissolver offgas vent piping upstream of V-77 resulting in release of chemical fumes	During normal operations the vent piping will be at a slight vacuum which will minimize leakage out of piping.	Leak in vent header	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
43.18.1.1	Scrap dissolver operations started without scrubber and acid POG system in operation resulting in release of chemical fumes	Operating procedures will specify support systems required for dissolver operations.	Failure to configure support systems prior to starting scrap dissolver operations	-2	Active Engineered Control – V-77 differential pressure switch interlock that will maintain dissolver feed isolation valves in closed position unless scrubber offgas system is in operation	Active Engineered Control – Acid POG system differential pressure switch interlock will maintain dissolver feed isolation valves in closed position unless acid POG system is in operation	-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of V-77 differential pressure switch interlock maintain valves in closed position when offgas system is not in service				Failure of V-77 differential pressure interlock switch maintain valves in closed position when offgas system is not in service	Acid POG system differential pressure switch interlock will maintain dissolver feed isolation valves in closed position unless acid POG system is in operation	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of acid POG system differential pressure switch interlock to maintain valves in closed position when offgas system is not in service				Failure of acid POG system differential pressure interlock switch to maintain valves in closed position when offgas system is not in service	V-77 differential pressure switch interlock that will maintain dissolver feed isolation valves in closed position unless scrubber offgas system is in operation	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
47.1.5.2	Damage to P-AH from no flow condition resulting in release of chemical fumes	Operator training on proper operation of equipment.	Pump recirculation line valve closed	-1	Administrative Control – Operating procedures and training prevent improper valve operation	Administrative Control – Tamper seal placed on recirculation line valve	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of operating procedures and training to prevent improper valve operation				Failure of operating procedures and training to prevent improper valve operation	Tamper seal placed on scrubber recirculation line valve	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure to install tamper seal				Failure to install tamper seal	Operating procedures and training prevent improper valve operation	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
47.3.1.1	Release of ammonium hydroxide liquid to containment and release of ammonia fumes		Overflow of TK-AH during tank fill operations	-1	Administrative Control – Procedural control on bulk tank filling operations	Enhanced Administrative Control – Tank TK-AH high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to follow procedure for bulk tank filling operations		Human error		Failure to follow procedure for bulk tank filling operations	Tank TK-AH high level alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of TK-AH high level alarm on CCS		Instrumentation failure		Failure of TK-AH high level alarm on CCS	Procedural control on bulk tank filling operations	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
47.16.1.1	Release of ammonium hydroxide liquid and fumes	Facility emergency response plan	Rupture of tank or associated piping	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
			Leak of tank or associated piping	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
49.1.7.1	No DIW flow to TK-DNA resulting in exposure to concentrated nitric acid liquid and fumes in downstream process lines with potential *for ion exchange resin* damage and column leak or rupture.	Operator monitoring of dilute nitric acid batch process.	Blocked DIW line	-1	Active Engineered Control – Tank TK-DNA high acid concentration switch interlock closes dilute acid header isolation valve	Administrative Control – Operator training and procedures	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of TK-DNA high acid concentration switch *interlock to close dilute acid* header isolation valve		*Instrumentation* failure		*Failure of TK-DNA* high acid concentration switch interlock to close dilute acid header isolation valve	*Administrative Control* – Operator training and procedures	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure to follow approved procedures		Instrumentation failure		Failure to follow approved procedures	Active Engineered Control – Tank TK-DNA high acid concentration switch interlock closes dilute acid header isolation valve	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
49.21.2.1	Release of concentrated nitric acid liquid and fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Rupture of tank or associated piping	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
			Leak of tank or associated piping	-1	*Passive Engineered* Control - Materials of construction compatible with process fluids	*Administrative Control* – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
FHA #4	Tank gallery fire results in release of chemical fumes from area storage tanks	Operator awareness during routine rounds prevents buildup of combustibles and sprinklers mitigate potential fire scenarios	OCB tank gallery fire due to general combustibles	-1	Administrative Control – Combustible loading program restricts combustible loading in the area	Administrative Control – Fire protection test, maintenance and inspection activities	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of combustible loading program to restrict combustibles in area		Human Error		Failure of combustible loading program to restrict combustibles in area	Administrative Control – Fire protection test, maintenance and inspection activities	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of protection test, maintenance and inspection activities to prevent fire hazard		Human Error		Failure of protection test, maintenance and inspection activities to prevent fire hazard	Administrative Control – Combustible loading program restricts combustible loading in the area	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
FHA #5	Conversion Area 2nd floor fire results in release of chemical fumes from area storage tanks	Operator awareness during routine rounds prevents buildup of combustibles	Conversion Area 2nd floor fire due to general combustibles	-1	Administrative Control – Combustible loading program restricts combustible loading in the area	Administrative Control – Fire protection test, maintenance and inspection activities	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of combustible loading program to restrict combustibles in area		Human Error		Failure of combustible loading program to restrict combustibles in area	Administrative Control – Fire protection test, maintenance and inspection activities	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of protection test, maintenance and inspection activities to prevent fire hazard		Human Error		Failure of protection test, maintenance and inspection activities to prevent fire hazard	Administrative Control – Combustible loading program restricts combustible loading in the area	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
FHA #6	Effluent building fire results in release of chemical fumes from area storage tanks	Operator awareness during routine rounds prevents buildup of combustibles and sprinklers mitigate potential fire scenarios	Effluent building fire due to general combustibles	-1	Administrative Control – Combustible loading program restricts combustible loading in the area	Administrative Control – Fire protection test, maintenance and inspection activities	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of combustible loading program to restrict combustibles in area		Human Error		Failure of combustible loading program to restrict combustibles in area	Administrative Control – Fire protection test, maintenance and inspection activities	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of protection test, maintenance and inspection activities to prevent fire hazard		Human Error		Failure of protection test, maintenance and inspection activities to prevent fire hazard	Administrative Control – Combustible loading program restricts combustible loading in the area	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
FHA #7	Explosion results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks	Calciner temperature instrumentation on CCS alerts operator to oxygen inleakage	Hydrogen explosion in calciner or off gas scrubber	-1	Active Engineering Control – Hydrogen supply interlocked closed on high oxygen concentration	Enhanced Administrative Control – Calciner high pressure alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of oxygen sensor to interlock hydrogen supply		Instrumentation failure		Failure of oxygen sensor to interlock hydrogen supply	Enhanced Administrative Control – Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Active Engineering Control – Hydrogen supply interlocked closed on high oxygen concentration	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
FHA #8	Explosion results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks	Differential pressure indicator provides indication of off-normal condition	Hydrogen leak into 2nd floor conversion area	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
FHA #9	Explosion results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks	Differential pressure indicator provides indication of off-normal condition	Hydrogen air dilution system explosion	-1	Active Engineering Control – Hydrogen supply interlocked closed on high hydrogen concentration	Active Engineering Control – Hydrogen supply interlocked closed on low dilution air flow	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of hydrogen supply valve to interlock closed on high oxygen concentration		Instrumentation failure		Failure of hydrogen supply valve to interlock closed on high hydrogen concentration	Active Engineering Control – Hydrogen supply interlocked closed on low dilution air flow	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of hydrogen supply valve to interlock closed on low dilution air flow		Instrumentation failure		Failure of hydrogen supply valve to interlock closed on low dilution air flow	Active Engineering Control – Hydrogen supply interlocked closed on high hydrogen concentration	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
FHA #10	Hydrogen torch fire results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks	Differential pressure indicator provides indication of off-normal condition	Hydrogen release and torch fire	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
25.1.2.1.A	Overflow from TK-50 resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	P-50 failure	-1	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U, C.	-1 -3	3 2	2 2	6 4
			P-50 not operating	-2	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U C.	-2 -4	3 1	2 2	6 2
			Closed valves in tank discharge line	-2	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U. C.	-2 -4	3 1	2 2	6 2
			Discharge line plugged	-2	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U, C.	-2 -4	3 1	2 2	6 2
25.1.2.1.B	Overflow from TK-51 resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	P-51 failure	-1	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U. C.	-1 -3	3 2	2 2	6 4
			P-51 not operating	-2	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U C.	-2 -4	3 1	2 2	6 2

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
			Closed valves in tank discharge line	-2	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U C	-2 -4	3 1	2 2	6 2
			Discharge line plugged	-2	Active Engineered Control – Tank high level switch interlock closes tank inlet isolation valves	NA	-2	NA	U C	-2 -4	3 1	2 2	6 2
25.4.2.1	Overflow from TK-51 resulting in release of chemical fumes	Operator routinely monitors level indication and deviation alarm would alert operator if level is outside of normal band. Procedures address corrective actions to prevent high level or overflow conditions.	P-51 shutdown resulting in backflow from stripper column V-52	0	Active Engineered Control – Pump shutdown/failure interlock closes TK-51 discharge valve	NA	-2	NA	U C	0 -2	3 1	2 2	6 2
			P-51 failure resulting in backflow from stripper column V-52	0	Active Engineered Control – Pump shutdown/failure interlock closes TK-51 discharge valve	NA	-2	-2	U C	0 -4	3 1	2 2	6 2
IROFS failure	Failure of pump shutdown/failure interlock to close TK-51 discharge valve		Instrumentation failure		Failure of pump shutdown/failure interlock to close TK-51 discharge valve	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	2 2	6 2
25.21.1.1	Leak in TK-51 resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	2 2	6 2
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	2 2	4 2

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	2 2	6 2
27.9.1.3	Over-pressurization of TK-50	Normal vent path is to blower and building exhaust.	Failure of ammonia scrubber vent pressure control valve PCV-542	-2	Passive Engineered Control – TK-50 overflow line	NA	-3	NA	U C	-2 -5	3 1	2 2	6 2
38.25.1.1	Potential airborne and personnel contamination		Spill of UO3 powder during drum handling operations	-1	Passive Engineered Control – Drum handling operations performed in hood	NA	-3	NA	U C	-1 -4	3 1	2 2	6 2
40.25.5.1	Leak concentrated nitric acid header in OCB resulting in release of acid fumes	In properly designed the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	2 2	6 2
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	2 2	4 2
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	2 2	6 2

Table 4-11
Radiological Safety Risk Assessment (Worker and Environmental)

Item	Deviation	Cause	Event Failure Frequency Index Number	Mitigative/ Preventative $IROFS_1$ and IROFS failure	Mitigative/ Preventative $IROFS_2$ and IROFS failure	$IROFS_1$ Effectiveness of Protection Index	$IROFS_2$ Effectiveness of Protection Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence												
Scenario OCB-RWC-7a												
12.1.10.1	No/Low Flow	Failure of blender exhaust blowback air to operate	-1	Administrative Control, Blender Pressure Indication	Passive Engineering Control, Vented Vessel (Blender)	-1	-3	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Blender Pressure Indication fails		NA	Blender Pressure Indication fails	Vessel (Blender) not vented	-1 dur=0	-3	U C	-1 -4	3 1	3 3	9 3
IROFS failure	Vessel (Blender) not vented		NA	Vessel (Blender) not vented	Blender Pressure Indication fails	-3 dur=0	-1	U C	-3 -4	2 1	3 3	6 3
12.1.8.1	No/Low Flow	Failure of instrument line purge air to blender pressure instrument	-1	Passive Engineering Control, Stainless steel material of construction (Blender)	Passive Engineering Control, Vented Vessel (Blender)	-3	-3	U C	-1 -7	3 1	3 3	9 3
IROFS failure	Material of construction not stainless steel		NA	Material of construction not stainless steel	Vessel (Blender) not vented	-3 dur=0	-3	U C	-3 -6	2 1	3 3	6 3
IROFS failure	Vessel (Blender) not vented		NA	Vessel (Blender) not vented	Material of construction not stainless steel	-3 dur=0	-3	U C	-3 -6	2 1	3 3	6 3
12.1.9.1	No/Low Flow	Plugging of blender exhaust	-1	Administrative Control, Blender Pressure Indication	Passive Engineering Control, Stainless steel material of construction (Blender)	-1	-3	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Blender Pressure Indication fails		NA	Blender Pressure Indication fails	Material of construction not stainless steel	-1 dur=0	-3	U C	-1 -4	3 1	3 3	9 3
IROFS failure	Material of construction not stainless steel		NA	Material of construction not stainless steel	Blender Pressure Indication fails	-3 dur=0	-1	U C	-3 -4	2 1	3 3	6 3

Item	Deviation	Cause	Event Failure Frequency Index Number	Mitigative/ Preventative IROFS, and IROFS failure	Mitigative/ Preventative IROFS, and IROFS failure	IROFS, Effectiveness of Protection Index	IROFS, Effectiveness of Protection Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
12.3.3.1	High Flow	Blowback solenoid fails on, resulting in high flow to blender exhaust filter	-1	Administrative Control, Blender Pressure Indication	Passive Engineering Control, Stainless steel material of construction (Blender)	-1	-3	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Blender Pressure Indication fails		NA	Blender Pressure Indication fails	Material of construction not stainless steel	-1 dur=0	-3	U C	-1 -4	3 1	3 3	9 3
IROFS failure	Material of construction not stainless steel		NA	Material of construction not stainless steel	Blender Pressure Indication fails	-3 dur=0	-1	U C	-3 -4	2 1	3 3	6 3
12.3.5.2	High Flow	High powder flow rate from hopper to blender	-1	Administrative Control, Blender Pressure Indication	Passive Engineering Control, Vented Vessel (Blender)	-1	-3	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Blender Pressure Indication fails		NA	Blender Pressure Indication fails	Vessel (Blender) not vented	-1 dur=0	-3	U C	-1 -4	3 1	3 3	9 3
IROFS failure	Vessel (Blender) not vented		NA	Vessel (Blender) not vented	Blender Pressure Indication fails	-3 dur=0	-1	U C	-3 -4	2 1	3 3	6 3
12.3.8.1	High Flow	High purge air flow rate in blender	-1	Administrative Control, Blender Pressure Indication	Passive Engineering Control, Vented Vessel (Blender)	-1	-3	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Blender Pressure Indication fails		NA	Blender Pressure Indication fails	Vessel (Blender) not vented	-1 dur=0	-3	U C	-1 -4	3 1	3 3	9 3
IROFS failure	Vessel (Blender) not vented		NA	Vessel (Blender) not vented	Blender Pressure Indication fails	-3 dur=0	-1	U C	-3 -4	2 1	3 3	6 3
Intermediate Consequence												
Scenario OCB-RWC-7a												
12.3.2.1	High flow	Blowback solenoid fails on, resulting in high flow to hopper lines	-1	Passive Engineering control vented vessel (Hopper)	NA	-3	NA	U C	-1 -4	3 1	2 2	6 2

Item	Deviation	Cause	Event Failure Frequency Index Number	Mitigative/ Preventative IROFS₁ and IROFS failure	Mitigative/ Preventative IROFS₂ and IROFS failure	IROFS₁ Effectiveness of Protection Index	IROFS₂ Effectiveness of Protection Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence												
Hydrogen Explosion in Calciner or Scrubber Off-Gas System												
Explosion Scenario 1	Air pulled into system	Piping or equipment failure	-1	Active Engineering Control, Oxygen Analyzer downstream of off-gas scrubber	Active Engineering Control, High/low hydrogen pressure interlocked with hydrogen supply valves	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Oxygen Analyzer Indication fails		NA	Oxygen Analyzer Indication fails	Buildup of explosive atmosphere due to valve/pressure interlock failure	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Buildup of explosive atmosphere due to valve/pressure interlock failure		NA	Buildup of explosive atmosphere due to valve/pressure interlock failure	Oxygen Analyzer Indication fails	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3
High Consequence												
Hydrogen Released Into 2nd Floor Conversion Area												
Explosion Scenario 2	Hydrogen Released from system containment into building	Piping or equipment failure	-1	Active Engineering Control, Vacuum-pressure system blower	Active Engineering Control;. high/low hydrogen pressure interlocked with hydrogen supply valves	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Vacuum-pressure system blower fails to maintain negative pressure on system		NA	Vacuum-pressure system blower fails to maintain negative pressure on system	Buildup of explosive atmosphere due to valve/pressure interlock failure	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Buildup of explosive atmosphere due to valve/pressure interlock failure		NA	Buildup of explosive atmosphere due to valve/pressure interlock failure	Vacuum-pressure system blower fails to maintain negative pressure on system	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3
High Consequence												
Hydrogen Air-Dilution System Explosion												
Explosion Scenario 3	Hydrogen enters explosive range	Failure of hydrogen air-dilution system	-1	Active Engineering Control, Hydrogen-air dilution blower	Active Engineering Control, Hydrogen gas detector downstream of air-dilution system	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Deviation	Cause	Event Failure Frequency Index Number	Mitigative/ Preventative IROFS$_1$ and IROFS failure	Mitigative/ Preventative IROFS$_2$ and IROFS failure	IROFS$_1$ Effectiveness of Protection Index	IROFS$_2$ Effectiveness of Protection Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
IROFS failure	Hydrogen-air dilution blower fails		NA	Hydrogen-air dilution blower fails	Hydrogen gas detector downstream of air-dilution system fails	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Hydrogen gas detector downstream of air-dilution system fails		NA	Hydrogen gas detector downstream of air-dilution system fails	Hydrogen-air dilution blower fails	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3
High Consequence												
Hydrogen Release and Torch Fire												
Explosion Scenario 4	Hydrogen Released from system containment	Piping or equipment failure	-1	Active Engineering Control, Vacuum-pressure system blower	Active Engineering Control, High/low hydrogen pressure interlocked with hydrogen supply valve	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Vacuum-pressure system blower fails to maintain negative pressure on system		NA	Vacuum-pressure system blower fails to maintain negative pressure on system	Buildup of explosive atmosphere due to valve/pressure interlock failure	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Buildup of explosive atmosphere due to valve/pressure interlock failure		NA	Buildup of explosive atmosphere due to valve/pressure interlock failure	Vacuum-pressure system blower fails to maintain negative pressure on system	-2 dur=0	-2	U C	-2 -4	3 1	3 3	9 3

Table 4-12
Environmental Chemical Risk Assessment

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
2.1.1.1	P-22 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-22 high casing temperature due to deadhead configuration	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Instrumentation failure	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Line plugging	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
3.1.7.1	P-23 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.		-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
9.1.2.2	P-38 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-38 high casing temperature due to deadhead configuration	-1	Passive Engineered Control -- Pump recirculation line	Enhanced Administrative Control -- Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
17.1.7.1	P-40 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-40 high casing temperature due to deadhead configuration	-1	Passive Engineered Control – Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
18.1.7.1	P-41 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-41 high casing temperature due to deadhead configuration	-1	Passive Engineered Control – Pump recirculation line	Active Engineered Control – Pump casing high temperature alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
20.1.6.1	P-43 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-43 high casing temperature due to deadhead configuration	-1	Passive Engineered Control – Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U: C:	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U: C:	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U: C:	-2 -4	3 1	3 3	9 3
23.1.5.1	P-47B explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-47B high casing temperature due to deadhead configuration	-1	Passive Engineered Control - Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U: C:	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U: C:	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U: C:	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
25.1.1.1	P-50 explosion due to ammonium nitrate	Ammonium nitrate is in aqueous solution far below concentrations where detonation is considered possible. Lag time in a dead-headed pump before solution would dry to the point where detonation were possible would take many hours or days, giving ample time for corrective action.	P-50 high casing temperature due to deadhead configuration	-1	Passive Engineered Control - Pump recirculation line	Enhanced Administrative Control – Pump casing high temperature alarm on CCS	-2	-2	U: C:	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to properly line up pump recirculation flow path		Human error		Failure to properly line up pump recirculation flow path	Pump casing high temperature alarm on CCS	-2 dur= -1	-2	U: C:	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of alarm to indicate pump casing high temperature condition		Instrumentation failure		Failure of alarm to indicate pump casing high temperature condition	Pump recirculation line	-2 dur= 0	-2	U: C:	-2 -4	3 1	3 3	9 3
25.21.1.2	Leak in liquid waste piping outside of building resulting in offsite release of acid fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U: C:	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U: C:	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U: C:	-2 -5	3 1	3 3	9 3
27.1.3.1	Overflow from TK-54 into other vessels through vent piping resulting in release of chemical fumes	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	Loss of TK-54 discharge flow	0	Active Engineered Control – Tank high level switch interlock closes feed isolation valve	Enhanced Administrative Control – Tank high level alarm on CCS	-2	-2	U: C:	0 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS₁ and IROFS failure	Mitigative/ Preventive IROFS₂ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of tank high level switch to close feed isolation valves		Instrumentation failure		Failure of tank high level switch to close feed isolation valves	Tank high level alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on tank high level		Instrumentation failure		Failure of CCS to alarm on tank high level	Tank high level switch interlock closes feed isolation valves	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
27.1.4.1	Over-pressurization of stripper columnV-52	E-53 cooling water inlet and outlet lines have temperature indication.	Loss of cooling water to overhead condenser E-53	-1	Active Engineered Control -- Steam supply shut off on stripper column high pressure	Enhanced Administrative Control - Stripper column high pressure alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of stripper high pressure steam supply shutoff interlock		Instrumentation failure		Failure of stripper high pressure steam supply shutoff interlock	Stripper column high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of CCS to alarm on stripper column high pressure		Instrumentation failure		Failure of CCS to alarm on stripper column high pressure	Steam supply shut off on stripper high pressure	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
27.1.5.1	Inadequate scrubbing in V-59 with release of ammonia vapors to the environment	Operator routinely monitors flow and ammonia concentration indications. Procedures address corrective actions to prevent exhaust stack high ammonia concentration conditions.	Inadequate DIW flow to V-59	-1	Enhanced Administrative Control - DIW to V-59 low flow alarm on CCS	Enhanced Administrative Control - Exhaust stack high ammonia concentration alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of DIW to V-59 low flow alarm on CCS		Instrumentation failure		Failure of DIW to V-59 low flow alarm on CCS	Exhaust stack high ammonia concentration alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of exhaust stack high ammonia concentration alarm on CCS		Instrumentation failure		Failure of exhaust stack high ammonia concentration alarm on CCS	DIW to V-59 low flow alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
27.1.6.1	Increased liquid level in V-59 resulting in release of ammonia vapors to the environment	Operator training on proper operation of equipment.	Ammonia recovery scrubber liquid discharge valve closed	-1	Administrative Control - Operating procedures and training prevent improper valve operation	Administrative Control - Tamper seal placed on scrubber discharge valve	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in *Depth*)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of operating procedures and training to prevent improper valve operation				Failure of operating procedures and training to prevent improper valve operation	Tamper seal placed on scrubber discharge valve	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure to install tamper seal				Failure to install tamper seal	Operating procedures and training prevent improper valve operation	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
27.9.1.1	Over-pressurization of TK-54	Overpressurization failure prevented by vent path through E-53 to V-52 relief valve.	Failure of ammonia scrubber vent pressure control valve PCV-542	-2	Passive Engineered Control - Pressure vent path through V-59	Enhanced Administrative Control – Tank/header high pressure alarm on CCS	-3	-2	U C	-2 -7	3 1	3 3	9 3
IROFS failure	Vent plugged		Mechanical failure		Vent plugged	Tank/header high pressure alarm on CCS	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure of high tank/header pressure alarm on CCS		Instrumentation failure		Failure of high tank/header pressure alarm on CCS	Pressure vent path through V-59	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
27.9.1.2	Over-pressurization of TK-AH	Overpressurization failure prevented by tank relief valve	Failure of ammonia scrubber vent pressure control valve PCV-542	-2	Passive Engineered Control - TK-AH vent path through V-59	Enhanced Administrative Control – Tank/header high pressure alarm on CCS	-3	-2	U C	-2 -7	3 1	3 3	9 3
IROFS failure	Vent plugged		Mechanical failure		Vent plugged	Tank/header high pressure alarm on CCS	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure of high tank/header pressure alarm on CCS		Instrumentation failure		Failure of tank/header high pressure alarm on CCS	Pressure vent path through V-59	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
27.17.1.1	Leak in V-52 resulting in release of chemical fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
38.7.1.2	Overflow from TK-70 resulting in release of chemical fumes and soluble uranium toxicity hazards	Operator routinely monitors level indication. Procedures address corrective actions to prevent high level or overflow conditions.	Violent reaction due to inadvertent addition of drum of enriched scrap material	-2	Administrative Control - Administrative controls on NUN dissolver feed material	Active Engineered Control: Enrichment monitor disables overhead crane operation to prevent transporting enriched material to the NUN dissolver hopper.	-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of enrichment monitor to disable overhead crane		Instrumentation failure		Enrichment monitor fails to disable overhead crane operation to prevent transporting enriched material to the NUN dissolver hopper.	Administrative controls on NUN dissolver feed material	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Loss of feed material control		Human error		Loss of feed material control	Enrichment monitor disables overhead crane operation to prevent transporting enriched material to the NUN dissolver hopper.	-2 dur= -2	-2	U C	-2 -6	3 1	3 3	9 3
47.1.5.2	Damage to P-AH from no flow condition resulting in release of chemical fumes	Operator training on proper operation of equipment.	Pump recirculation line valve closed	-1	Administrative Control – Operating procedures and training prevent improper valve operation	Administrative Control – Tamper seal placed on recirculation line valve	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of operating procedures and training to prevent improper valve operation				Failure of operating procedures and training to prevent improper valve operation	Tamper seal placed on scrubber recirculation line valve	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure to install tamper seal				Failure to install tamper seal	Operating procedures and training prevent improper valve operation	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
47.3.1.1	Release of ammonium hydroxide liquid to containment and release of ammonia fumes		Overflow of TK-AH during tank fill operations	-1	Administrative Control – Procedural control on bulk tank filling operations	Enhanced Administrative Control – Tank TK-AH high level alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure to follow procedure for bulk tank filling operations		Human error		Failure to follow procedure for bulk tank filling operations	Tank TK-AH high level alarm on CCS	-2 dur= -1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of TK-AH high level alarm on CCS		Instrumentation failure		Failure of TK-AH high level alarm on CCS	Procedural control on bulk tank filling operations	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
47.16.1.1	Release of ammonium hydroxide liquid and fumes	Facility emergency response plan	Rupture of tank or associated piping	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
			Leak of tank or associated piping	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		Failure to inspect and maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
49.21.2.1	Release of concentrated nitric acid liquid and fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Rupture of tank or associated piping	-1	Passive Engineered Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
			Leak of tank or associated piping	-1	*Passive Engineered* Control - Materials of construction compatible with process fluids	Administrative Control – Periodic inspection and maintenance procedures	-3	-2	U C	-1 -6	3 1	3 3	9 3
IROFS failure	Failure to use specified materials		Human error		Failure to use specified materials	Periodic inspection and maintenance procedures	-3 dur= 0	-2	U C	-3 -5	2 1	3 3	6 3
IROFS failure	Failure to inspect and maintain equipment		Human error		*Failure to inspect and* maintain equipment	Materials of construction compatible with process fluids	-2 dur= 0	-3	U C	-2 -5	3 1	3 3	9 3
FHA #4	Tank gallery fire results in release of chemical fumes from area storage tanks	Operator awareness during routine rounds prevents buildup of combustibles and *sprinklers mitigate potential fire scenarios*	OCB tank gallery fire due to general *combustibles*	-1	Administrative Control – Combustible loading program restricts combustible loading in the area	Administrative Control – Fire protection test, maintenance and inspection activities	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of combustible loading program to restrict combustibles in area		Human Error		Failure of combustible loading program to restrict combustibles in area	Administrative Control – Fire protection test, maintenance and inspection activities	-2 dur=-1	-2	U C	-2 -5	3 1	3 3	9 3
IROFS failure	Failure of protection test, maintenance and inspection activities to prevent fire hazard		Human Error		Failure of protection test, maintenance and inspection activities to prevent fire hazard	Administrative Control – Combustible loading program restricts combustible loading in the area	-2 dur=-1	-2	U C	-2 -5	3 1	3 3	9 3
FHA #6	Effluent building fire results in release of chemical fumes from area storage tanks	Operator awareness during routine rounds prevents buildup of combustibles and sprinklers mitigate potential fire scenarios	Effluent building fire due to general combustibles	-1	Administrative Control – Combustible loading program restricts combustible loading in the area	*Administrative* Control – Fire protection test, maintenance and inspection activities	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of combustible loading program to restrict combustibles in area		Human Error		Failure of combustible loading program to *restrict combustibles in* area	Administrative Control – Fire protection test, maintenance and inspection activities	-2 dur=-1	-2	U C	-2 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of protection test, maintenance and inspection activities to prevent fire hazard		Human Error		Failure of protection test, maintenance and inspection activities to prevent fire hazard	Administrative Control – Combustible loading program restricts combustible loading in the area	-2 dur=-1	-2	U C	-2 -5	3 1	3 3	9 3
FHA #7	*Explosion results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks*	Calciner temperature instrumentation on CCS alerts operator to oxygen inleakage	Hydrogen explosion in calciner or off gas scrubber	-1	Active Engineering Control – Hydrogen supply interlocked closed on high oxygen concentration	Enhanced Administrative Control – Calciner high pressure alarm on CCS	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of oxygen sensor to interlock hydrogen supply		Instrumentation failure		Failure of oxygen sensor to interlock hydrogen supply	Enhanced Administrative Control – Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Active Engineering Control – Hydrogen supply interlocked closed on high oxygen concentration	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
FHA #8	Explosion results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks	Differential pressure indicator provides indication of off-normal condition	Hydrogen leak into 2nd floor conversion area	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
FHA #9	Explosion results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks	*Differential pressure indicator provides indication of off-normal condition*	Hydrogen air dilution system explosion	-1	Active Engineering Control – Hydrogen supply interlocked closed on high hydrogen concentration	Active Engineering Control – Hydrogen supply interlocked closed on low dilution air flow	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
High Consequence Events													
IROFS failure	Failure of hydrogen supply valve to interlock closed on high oxygen concentration		Instrumentation failure		Failure of hydrogen supply valve to interlock closed on high hydrogen concentration	Active Engineering Control – Hydrogen supply interlocked closed on low dilution air flow	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of hydrogen supply valve to interlock closed on low dilution air flow		Instrumentation failure		Failure of hydrogen supply valve to interlock closed on low dilution air flow	Active Engineering Control – Hydrogen supply interlocked closed on high hydrogen concentration	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
FHA #10	Hydrogen torch fire results in conversion area 2nd floor fire with release of chemical fumes from area storage tanks	Differential pressure indicator provides indication of off-normal condition	Hydrogen release and torch fire	-1	Enhanced Administrative Control – Calciner high pressure alarm on CCS	Active Engineered Control – Calciner high pressure switch interlock shuts down calciner	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure alarm on CCS		Instrumentation failure		Failure of calciner high pressure alarm on CCS	Calciner high pressure switch interlock shuts down calciner	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3
IROFS failure	Failure of calciner high pressure switch interlock to shut down calciner		Instrumentation failure		Failure of calciner high pressure switch interlock to shut down calciner	Calciner high pressure alarm on CCS	-2 dur= 0	-2	U C	-2 -4	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
2.24.1.1	Leak from 23% ammonia *feed line to TK-22 resulting* in release of chemical fumes		Line rupture	-1	Passive Engineering Control, Materials of construction (stainless steel)	Administrative Control, Maintenance procedures and training	-3	-1	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Mechanical failure of stainless steel pipe		Mechanical failure		Mechanical failure of stainless steel pipe	Administrative Control, Maintenance procedures and training	-3 dur=-2	-1	U C	-3 -6	2 1	3 3.	6 3
IROFS failure	*Maintenance is not* performed correctly and work acceptance criteria fails		Human error		Maintenance is not performed correctly and work acceptance criteria fails	Passive Engineering Control, Materials of construction (stainless steel)	-1 dur=-2	-3	U C	-1 -6	3 1	3 3	9 3
5.1.5.2	High moisture content in the feed causing over-pressurization of the calciner resulting in release of off-gas to room	Dryer operates at elevated temperatures to reduce the moisture content of the ADU solids before sending to calciner; downstream filter differential pressure indicators provide indication *of off-normal condition;* Instruments analyze calciner discharge moisture content	Pluggage in dryer off-gas line	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Pluggage in dryer off-gas *filter*	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
5.3.1.1	High moisture content in the feed causing over-pressurization of the calciner resulting in release of off-gas to room	Dryer operates at elevated temperatures to reduce the moisture content of the ADU solids before sending to calciner; Instruments analyze calciner discharge moisture content	Residence time in dryer too short	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
5.12.1.1	High moisture content in the feed causing over-pressurization of the calciner resulting release of off-gas to room	Off-normal condition of heaters will be indicated on CCS; downstream filter differential pressure indicators provide indication of off-normal condition; Instruments analyze calciner discharge moisture content	Loss of dryer heater	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Dryer heater setpoint too low	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.1.3.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Procedures and training: operator responds to off-normal condition of calciner tube rotation as indicated by CCS	Calciner tube rotation failure	0	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	0 -4	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.1.5.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Off-normal condition at rotary valve indicated at CCS Instruments analyze calciner discharge moisture content	Rotary valve on calciner discharge (FV-32D) fails	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS, and IROFS failure	Mitigative/ Preventive IROFS, and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
			Rotary valve on calciner discharge (FV-32D) plugs	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.1.6.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Instruments analyze calciner discharge moisture content	Rear breech of calciner plugs	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
6.1.7.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Downstream filter differential pressure indicators provide indication of off-normal condition Instruments analyze calciner discharge moisture content	Powder plugs off-gas line	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.1.11.1	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Blinding of primary filter, V-32F	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
6.1.12.1	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Blinding of back filter, V-32B	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.1.13.1	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Failure of filter rotary valve	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
			Bridging at discharge of primary filter	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.2.2.1	Calciner over-pressurization resulting in release of off-gas to room	Operator sets N2 flow at rotameter Downstream blowers maintain a negative pressure within the calciner pulling off-gases from the calciner and exhausting from stack	High N2 flow through calciner	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.2.3.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Excessive product from add-back system during normal operations	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3

Item	Scenario	Controls (Defense In Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS1 and IROFS failure	Mitigative/ Preventive IROFS2 and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.2.4.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Downstream filter differential pressure indicators provide indication of off-normal condition Instruments analyze calciner discharge moisture content	Excessive ADU inlet flow to calciner	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
6.2.5.5	Calciner over-pressurization resulting in release of off-gas to room	Operator sets H2 flow at rotameter Downstream blowers maintain a negative pressure within the calciner pulling off-gases from the calciner and exhausting from stack	High H2 flow through calciner	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
6.12.2.1	Calciner tube plugged, restricting gas flow, and pressurizing discharge end resulting in release of off-gas to room	Off-normal condition of off-gas heat trace should display at CCS Instruments analyze calciner discharge moisture content Downstream filter differential pressure indicators provide indication of off-normal condition	Failure of off-gas heat trace resulting in wet powder	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
7.13.5	Calciner over-pressurization resulting in release of off-gas to room	Upstream filter differential pressure indicators provide indication of off-normal condition Off-normal condition on off-gas blower indicated at CCS Instruments analyze calciner discharge moisture content	Off-gas blower (B-38B) fails	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
7.17.9.2	Personnel exposure to ammonia fumes/release of off-gas to room		Leak in V-38B bottoms line	-2	Passive Engineering Control, Materials of construction	Administrative Control, Maintenance procedures and training	-3	-2	U C	-2 -7	3 1	3 3	9 3
IROFS failure	Mechanical failure of materials of construction		Mechanical failure		Mechanical failure of materials of construction	Administrative Control, Maintenance procedures and training	-3 dur=-2	-1	U C	-3 -6	2 1	3 3	6 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Maintenance is not performed correctly and work acceptance criteria fails		Human error		Maintenance is not performed correctly and work acceptance criteria fails	Passive Engineering Control, Materials of construction	-1 dur=-2	-3	U C	-1 -6	3 1	3 3	9 3
7.18.2.2	High moisture content in the feed to the calciner, leading to calciner over-pressurization resulting in release of off-gas to room	Materials of construction Maintenance procedures and training	Leak of cooling water into calciner off-gas line	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
7.18.2.5	Calciner over-pressurization resulting in release of off-gas to room	Materials of construction Maintenance procedures and training	Leak of cooling water into calciner off-gas line	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive IROFS$_1$ and IROFS failure	Mitigative/ Preventive IROFS$_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index	[illegible]	Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
7.19.3.4	High moisture content in the feed to the calciner, leading to calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Packing support plate fails resulting in plugged column	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
7.19.3.7	Calciner over-pressurization resulting in release of off-gas to room	Differential pressure indicator provides indication of off-normal condition	Packing support plate fails resulting in plugged column	-1	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into dryer	-2	-2	U C	-1 -5	3 1	3 3	9 3
IROFS failure	Failure of enhanced administrative control		Human error		Failure of enhanced administrative control; alarm or response to alarm does not occur	Active Engineering Control, high-high pressure at PI-321 shuts off feed and sweep gases into calciner	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3

Item	Scenario	Controls (Defense in Depth)	Cause	Event Failure Frequency Index Number	Mitigative / Preventive $IROFS_1$ and IROFS failure	Mitigative/ Preventive $IROFS_2$ and IROFS failure	IROFS1 Failure Frequency Index	IROFS2 Failure Frequency Index		Likelihood Index T	Likelihood Category	Consequence Category	Risk Index
Intermediate Consequence Events													
IROFS failure	Failure of PI-321 to shut off feed and sweep gases into calciner		Mechanical failure		Failure of PI-321 to shut off feed and sweep gases into calciner	Enhanced Administrative Control, PI-322 alarms on high pressure requiring operator response	-2 dur=-2	-2	U C	-2 -6	3 1	3 3	9 3
49.1.2.1	Damage to P-CNA from no flow condition resulting in release of chemical fumes	Operator training on proper operation of equipment.	Pump recirculation line valve closed	-1	Enhanced administrative control – System valve lineup	NA	-2	NA	U C	-1 -3	3 2	2 2	6 4
49.1.11.1	Release of concentrated nitric acid liquid to containment and release of acid fumes	Delivery of acid is not scheduled until adequate room exists in the tank to receive the contents of the tanker.	Overflow of TK-CNA during tank fill operations	-1	Enhanced administrative control – Operator response to LA-CNAH tank high level alarm	NA	-2	NA	U C	-1 -3	3 2	3 2	9 4
49.21.3.2	Leak in TK-DNA or associated piping outside of building resulting in offsite release of acid fumes	In properly designed and manufactured equipment the corrosion rate is low and periodic inspections provide a large margin of safety.	Corrosion	-1	Passive engineered control - TK-DNA and associated piping are constructed and tested in accordance with applicable ASME codes	Enhanced administrative control – Tank/piping maintenance and inspection program	-2	-2	U C	-1 -5	3 1	2 2	6 2
IROFS failure	Loss of tank or piping integrity		Mechanical failure		Loss of tank or piping integrity		-2	-2	U C	-2 -4	3 1	2 2	6 2
IROFS failure	Failure to perform routine maintenance and inspection		Human error		Failure to perform routine maintenance and inspection		-2	-2	U C	-2 -4	3 1	2 2	6 2

4.4 MANAGEMENT MEASURES FOR IROFS

Management Measures are applied to IROFS to ensure they are available and reliable to perform their required function when needed, as specified in 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, and
- Other Quality Assurance Elements.

The type of IROFS control, 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 are Active Engineered, Passive Engineered, Administrative, and Enhanced Administrative. The management measures appropriate for each type of control are shown in Table 4-14.

Not all of the listed management measures would be applied to each IROFS. The management measures applied to a specific IROFS may be graded commensurate with the level of risk reduction credited for the particular 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 4-14 identifies how management measures are applied in a graded approach based on Risk Reduction levels (Level A or B) credited in the ISA Summary. IROFS credited with a high level of risk reduction (those corresponding to High and/or Intermediate consequence accident sequences (Level A)) will require application of more management measures to ensure a high level of reliability. IROFS credited with a moderate level (those corresponding to Intermediate consequence accident sequences (Level B)) of risk reduction, or intermediate failure likelihood, may have a reduced level of management measures applied. 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 4-14 are applied based on the type of control to ensure that the credited IROFS failure index meets the risk index specified or the design base thresholds for events associated with natural phenomena. Information to justify a deviation from a management measure contained in Table 4-14 associated with a specific IROFS will be documented.

Table 4-14 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 4-14 will require functional testing. Documentation of the above steps will be maintained in the ISA files for individual IROFS.

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".

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.

Table 4-14
Management Measure for IROFS

CONTROL TYPE/Measures	RISK REDUCTION LEVEL A: IROFS credited with a high level of Risk Reduction for High or Intermediate consequence events	RISK REDUCTION LEVEL B: IROFS credited with a moderate level of Risk Reduction for Intermediate consequence events
ACTIVE ENGINEERED CONTROLS		
Periodic Functional Test	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	
Maintenance	x	
PASSIVE CONTROLS		
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	
Maintenance	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	
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	
Maintenance	x	
Calibration	X	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 OCB/EPB operations consisted of 5-8 members (additional personnel were included as necessary). The minimum team was defined to meet the requirements of 10 CFR 70.62. The team had an appointed Team Leader and at least one member knowledgeable in each of the following areas for the subject system: 1) criticality safety, 2) radiological safety, 3) fire safety, 4) chemical process safety, 5) project engineering, and 6) 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 Chapter 3, Integrated Safety Analysis (ISA) (Reference 6) . Guidance is also provided in NUREG-1513,(Reference 7) and the AIChE publication, "Guidelines for Hazard Evaluation Procedures." (Reference 1)

The ISA Team for the OCB/EPB consisted of the following personnel:

- Thomas Barry, Fire Safety, HSB Professional Loss Control (PLC)
- Joseph Chew, Industrial Safety, Nuclear Fuel Services, NFS
- Michael Corum, Nuclear Criticality Safety, Nuclear Safety Associates (NSA)
- Edward Foster, Radiological Safety, Framatome ANP (FANP)
- Lonnie Gerrald, Nuclear Criticality Safety, FANP
- Scott Gizzie, Nuclear Criticality Safety, NFS
- Andrew Greene, Process Engineer, FANP
- Jack Gump, Fire Safety, HSB PLC
- Charlie Holman, Process Engineer, FANP
- David Hopson, ISA Team Leader, NFS (ISA Team Leader training, Process Safety Institute, Knoxville, TN)
- Mike Kirkman, Process Engineer, FANP
- Clark Lewis, Nuclear Criticality Safety, NFS

- Andy Mix, Process Operator, FANP
- Richard Montgomery, Nuclear Criticality Safety, NFS
- Dave Moore, PHA Team Leader, FANP
- William Newmyer, Nuclear Criticality Safety, NSA
- Leland Powell, Industrial Safety, FANP
- Kevin Roberts, Health Physicist, NSA
- Sonya Sanders, Health Physicist, NFS
- Sam Skiles, Nuclear Criticality Safety, NSA
- Gail Tapp, Industrial Safety, NFS
- Cliff Yeager, Process Engineer, FANP
- Jerald Zito, Chemical Safety, FANP

Table 5-1 ISA Team Members

ISA TEAM LEADER	CRITICALITY SAFETY	RADIOLOGICAL SAFETY	FIRE/INDUSTRIAL SAFETY	CHEMICAL SAFETY	PROJECT ENGINEERING / MAINTENANCE/ OPERATIONAL
D. Hopson D. Moore	M. Corum L. Gerrald S. Gizzie C. Lewis W. Newmyer R. Montgomery S. Skiles	E. Foster K. Roberts S. Sanders	T. Barry J. Chew J. Gump L. Powell	G. Tapp J. Zito C. Mason	A. Greene C. Holman M. Kirkman A. Mix C. Yeager

5.2 ISA METHOD

The ISA is conducted in basically seven phases: 1. Individual and specific hazards analyses are performed to identify hazards and accident sequences. 2. From the hazard analyses, specific accident sequences are defined for consequence analysis. 3. Accident consequences are determined for the defined accident sequences based on unmitigated conditions for comparison with the 10 CFR 70.61 exposure criteria. 4. For which each high or intermediate consequence event determine if the active, passive, or administrative controls proposed are adequate to make the postulated events highly unlikely or unlikely. 5. IROFS are identified which control all accidents resulting in consequences of concern to an acceptable risk. 6. The IROFS list is generated and evaluated for adequacy. 7. Develop 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). The process systems are subdivided into discrete nodes for this analysis. The nodes for the OCB/EPB PHA are provided in **Table 5-1**. 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.

Table 5-1
Study Nodes for OCB/EPB HAZOP

Node	Description
1	Feed tanks, associated equipment, and piping - P&ID 520-PREC-210 sheet 1
2	Precipitation tank, associated equipment and piping - P&ID 520-PREC-210 sheet 2
3	Centrifuge feed tank, associated equipment, and connected piping - P&ID 520-PREC-210 sheet 3
4	ADU Centrifuge, discharge screw and connected piping - P&ID 520-PREC-210 sheet 3
5	ADU Dryer including off-gas filters, oil heater, associated equipment, and connected piping - P&ID 520-D/C-210 sheet 1 & 10
6	Calciner including recycle vessel, off-gas filters, associated equipment, and connected piping - P&ID 520-D/C-210 sheet 2, 3 & 11
7	Base off-gas scrubber, associated equipment, and connected piping - P&ID 520-D/C-210 sheet 12
8	Acid off-gas scrubber, associated equipment, and connected piping - P&ID 520-D/C-210 sheet 12
9	Process off-gas scrubber condensate tank - P&ID 520-D/C-210 sheet 12
10	Calcined powder receiver and oxidizer, associated equipment, and connected piping - P&ID 520-D/C-210 sheet 4 & 5
11	Powder loadout station including associated equipment and connected piping - P&ID 520-D/C-210 sheet 6
12	Calcined powder hopper and connected piping - P&ID 520-D/C-210 sheet 7 and Calcined powder Blender and connected

Node	Description
	piping - P&ID 520-D/C-210 sheet 7 and Pail fill station, associated equipment and connected piping - P&ID 520-D/C-210 sheet 8
13	Calcined powder Blender and connected piping - P&ID 520-D/C-210 sheet 7) Covered in node 12
14	Pail fill station, associated equipment and connected piping - P&ID 520-D/C-210 sheet 8) Covered in 12
15	Powder add back station, associated equipment and connected piping - P&ID 520-D/C-210 sheet 9
16	Central vac station, associated equipment and connected piping - P&ID 520-D/C-210 sheet 9
17	Centrifuge centrate tank, associated equipment and connected piping - P&ID 520-UREC-210 sheet 1
18	Crossflow filter feed tank, crossflow filter, pump, and connected piping - P&ID 520-UREC-210 sheet 2
19	Crossflow Filter and connected piping - P&ID 520-UREC-210 sheet 2 Covered in node 18
20	Ion exchange feed tanks, filters, and connected piping - P&ID 520-UREC-210 sheet 3
21	Ion exchange columns and connected piping - P&ID 520-UREC-210 sheet 3, 4 & 5
22	Eluate storage tanks, associated equipment, and connected piping - P&ID 520-UREC-210 sheet 6
23	Miscellaneous uranium solution storage tanks, associated equipment, and connected piping - P&ID 520-UREC-210 sheet 7
24	Ammonia recovery receipt tank and associated equipment and connected piping - P&ID 520-AR-210 sheet 1) Covered in node 25
25	Ammonia recovery receipt tank, feed tank, associated equipment, and connected piping - P&ID 520-AR
26	Ammonia recovery feed preheater and bottoms cooler and connected piping - P&ID 520-AR-210 sheet 2 Covered in node 27
27	Ammonia recovery stripper column, feed heater, bottoms cooler, overheads condenser, distillate tank, scrubber, associated equipment, and connected piping - P&ID 520-AR-210 sheet 2-4
28	Ammonia distillate tank including pump and connected piping - P&ID 520-AR-210 sheet 4 Covered in 27
29	Ammonia recovery scrubber and connected piping - P&ID 520-AR-210 sheet 4 Covered in node 27

Node	Description
30	Liquid waste evaporator feed tank, evaporator, heat exchangers, bottoms tanks, overhead tanks, associated equipment, and connected piping - P&ID 520-LW-210 sheets 1-4
31	Liquid waste evaporator including cooler, steam condensate tank, pump and connected piping - P&ID 520-LW-210 sheet 2 Covered in node 30
32	Evaporator overheads condenser, tanks and piping - P&ID 520-LW-210 sheet 3 Covered in node 30
33	Evaporator bottoms tanks, pumps, and piping - P&ID 520-LW-210 sheet 4) Covered in node 30
34	Solidifier bulk storage hopper, associated equipment and piping - P&ID 530-LW-210 sheet 7 Covered in 35
35	Waste Stabilization Bulk Storage Silos, Solids Hopper, batch ribbon mixer, waste container station, associated equipment, and piping - P&ID 530-LW-210 sheet 5 & 7
36	Steam boiler, feed tank, treatment chemicals, associated equipment, and piping - P&ID 520-LW-210 sheet
37	Natural uranium dissolver hood including drum handling equipment - P&ID 520-NUN-210 sheet 1 Covered in node 38
38	Natural uranium hood including drum handling equipment, dissolver, storage tank, loadout station, associated equipment, and piping - P&ID 520-NUN-210 sheet 1 & 510-NUN-210 sheet 1
39	Scrap uranium dissolver feed drum station, associated equipment, and piping - P&ID 520-DISS-210 sheet 1 Covered in node 40
40	Scrap uranium feed station, dissolvers, acid makeup tank, receiver tank, associated equipment, and piping - P&ID 520-DISS-210 sheet 1-3
41	Scrap dissolvers, associated equipment, and piping - P&ID 520-DISS-210 sheet 2 Covered in node 40
42	Dissolved scrap receiver tank, associated equipment, and piping – P&ID 520-DISS-210 sheet 3 Covered in node 40
43	Scrap dissolver off-gas scrubber, recirculation tank, associated equipment, and piping - P&ID 520-DISS-210 sheet 3
44	Natural uranyl nitrate solution storage tank and loadout station including associated equipment and piping - P&ID 510-NUN-

Node	Description
	210 sheet 1) Covered in node 38
45	Hydrogen storage tank, associated equipment, and piping - Block Diagram – Vendor unit
46	Liquid Nitrogen tank, associated equipment, and piping - Block Diagram – Vendor unit
47	Aqueous ammonia tank, associated equipment, and piping - P&ID 520-CHEM-210 sheet 3
48	NAOH Tank and Associated Piping - P&ID 520-CHEM-210 sheet 3
49	Nitric Acid Receiving, Storage, Dilution and Associated Equipment and Piping- P&ID 520-CHEM-210 sheet 2
50	Deionized water Production, Storage and Associated Equipment and Piping - P&ID 520-CHEM-210 sheet 1
51	Global Issues

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 OCB/EPB, the "HAZOP" methodology was selected. This methodology involves a detailed evaluation by the ISA team for each OCB/EPB 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 5-3). The results of the consequence analysis for the OCB/EPB 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 limits specified 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 OCB/EPB process. The risk assessment and final IROFS defined in the NCSEs are provided in Sections 4.3 and 6.1 respectively.

Fire Hazards Analysis

A Fire Hazards Analysis (FHA) was conducted for the OCB/EPB (Reference 9). 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 OCB/EPB 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.

5.2.2.1. Integration

To meet NRC requirements the ISA is, strictly speaking, concerned only with major events (i.e., high or intermediate consequences) of concern—and the IROFS necessarily applied to them to meet the performance criteria in 10 CFR 70.61. 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 Risk Categorization

In order to meet the performance requirements listed in 10 CFR 70.61, all credible High consequence accident sequences and all credible Intermediate consequence accident sequences shall be shown to be Highly Unlikely and Unlikely respectively, upon application of the proposed IROFS. Risk Assessment, as described below, presents a consequence-likelihood methodology by which this evaluation is performed. The results of the Risk Assessment for the OCB/EPB are summarized in Section 4.3 of this report. Additional risk assessment methodology for criticality safety scenarios is documented in the process NCSEs.

5.2.3.1. Consequence Category

For each credible accident sequence identified, a Consequence Category number is assigned (1, 2 or 3). The Consequence Category is assigned based on the specific radiological, chemical, or fire consequences calculated for the sequence, industry standards, engineering judgment, analytical data, and/or any other applicable information. The Consequence Categories and corresponding consequence levels are defined in **Table 5-3** as follows:

Table 5-3: 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 to workers 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.

5.2.3.2. Initiating Event Frequency

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 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 Frequency is defined as the probability of occurrence of the initiating event or initiating set of conditions. The index assignments are defined in Table 5-4.

Table 5-4: Initiating Event Index

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.

5.2.3.3. Identification of IROFS

Applicable IROFS are identified and assigned to all High or Intermediate consequence accident scenarios.

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 sub-systems must be:

- Designed to prevent or mitigate specific, potentially hazardous events. Each identified potential hazard will 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 will 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 their 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 Failure Index as specified in Table 5-5. The Failure Index is defined as the probability that the identified controls will prevent or mitigate the accidental consequence given the initiating event (or set of conditions) occurs. The Failure Index is assigned to each IROFS based on industry accepted values, past experience, engineering judgment, analytical data, and/or any other applicable information. The numerical assignments for the IROFS Failure Index are provided in Table 5-5.

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 database does not represent failure rates for IROFS protected by management measures as required in 10 CFR 70, Subpart H. The Savannah River 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 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 Date Base Development document is applicable to the BLEU Complex in that the Savannah River Site provides for operations such as storage and dissolution similar to the BLEU Complex operations. In addition, the database is particularly focused to non-reactor nuclear facilities.

The values in Table 5-5 are a minimum guide for index assignment, and if applicable, NFS may choose to assign conservatism to the indices used in risk assessment, 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 Frequency Index is not assigned. Instead, the IROFS Failure Index is selected for the IROFS from Table 5-5. The IROFS that triggers the accident scenario is assigned a Failure Duration Index as specified in Table 5-6. The Failure Duration Index is a qualitative measurement of the time that 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 interlocks in active engineered controls or alarms used in administrative controls are determined by engineering analysis that takes into account safety limits, instrument and system accuracy (from vendors), response time, anticipated instrument drift (based on vendor recommendations and operating experience), and other performance factors as appropriate. Setpoints are generally set very conservatively to ensure that the IROFS performance is reliable and making statistical calculations unnecessary. Calibration and functional test frequencies are also determined based on this data. 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 5-5: IROFS Failure 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 non-routine 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.

Table 5-6: 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}	

5.2.3.4. 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 and the IROFS Failure Frequency Index(s). If the initiating event is an IROFS failure, then the Controlled Likelihood Index T is calculated by summing the IROFS Failure Frequency 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 Frequency Index as applicable. Controlled and Uncontrolled Likelihood Categories are then assigned from Table 5-7 based on the respective Likelihood Index.

Table 5-7 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 and Likelihood Categories for all credible High or Intermediate consequence accident scenarios are assigned and documented in Section 4.3.

5.2.3.5. Resultant Risk Category

The qualitative values for the Likelihood and Consequence Categories are plotted on the Risk Matrix (Table 5-8) 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 5-8. As shown in Table 5-8, a risk greater than 4 is unacceptable and does not meet the 10CFR70.61 performance requirements.

Table 5-8: 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.*

5.2.4 IROFS List

Once the proposed IROFS have been evaluated through Risk Assessment, a final set of IROFS is generated. The final set of IROFS has 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 OCB/EPB

6.1 IROFS AND MANAGEMENT MEASURES FOR OCB/EPB

Table 6-1 defines and provides details about the IROFS and Management Measures for the OCB/EPB.

The information provided in the IROFS table forms the basis for development of procedures, postings, controlled equipment lists, and other IROFS implementing documents. The development of Management Measures (MM) is further defined in Section 4.4 of the ISA Summary.

Table 6-1
IROFS for OCB and EPB

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
			OCB Precipitation			
[redacted]	Overflow line for Tank 20 - provides protection against backflow to unfavorable geometry utility supply tanks and UN storage tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line is plugged during operation or an unfavorable geometry container is beneath the overflow line	High Criticality	Backflow-1 Backflow-2 Backflow-3 Backflow-4 Backflow-5 Spill-5	A
[redacted]	Overflow line for Tank 21 - provides protection against backflow to unfavorable geometry utility supply tanks and UN storage tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line is plugged during operation or an unfavorable geometry container is beneath the overflow line	High Criticality	Backflow-1 Backflow-2 Backflow-3 Backflow-4 Backflow-5 Spill-5	A
[redacted]	Overflow line for Tank 22 - provides protection against backflow to unfavorable geometry utility supply tanks and UN storage tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line is plugged during operation or an unfavorable geometry container is beneath the overflow line	High Criticality and Chemical	Backflow-1 Backflow-2 Backflow-3 Backflow-4 Backflow-5 Spill-5 2.14.1.3	A
[redacted]	Overflow line for Tank 23 - provides protection against backflow to unfavorable geometry utility supply tanks and UN storage tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line is plugged during operation or an unfavorable geometry container is beneath the overflow line	High Criticality	Backflow-1 Backflow-2 Backflow-3 Backflow-4 Backflow-5 Spill-5 3.14.1.3	A
[redacted]	DI Water supply valve closes and dual feed line valves to Tank 20A close when high-high level switch reaches its set point preventing backflow of uranium into the UN storage tanks or the DI Water supply tanks.	Active Engineered Control	Interlock fails to close tank feed valves and DIW supply valve on tank high level condition	High Criticality	Backflow-1 Backflow-2	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Three-way valve prevents flow of uranium solution into DI water or DNA supply tanks.	Passive Engineered Control	Three-way valve allows flow from centrifuge feed line to DIW/DNA supply line	High Criticality	Backflow-6	A
[redacted]	DI Water supply valve and DNA supply valve close when flow valve to centrifuge is open (and visa versa) preventing backflow of uranium into the DI Water or DNA supply tanks.	Active Engineered Control	Interlock allows centrifuge feed valve and DIW/DNA supply valves to be open simultaneously	High Criticality	Backflow-6	A
[redacted]	Operator responds to P-22 pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	2.1.1.1	A
[redacted]	Pump recirculation line for P-22 provides flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	2.1.1.1	A
[redacted]	Operator responds to P-23 pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	3.1.7.1	A
[redacted]	Pump recirculation line for P-23 provides flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	3.1.7.1	A
[redacted]	Feed valves close when high tank level is sensed, preventing backflow from TK-22 into the vent system.	Active Engineered Control	Interlock fails to close tank feed valves on tank high level condition	High Chemical	2.14.1.3	A
[redacted]	Feed valves close when high tank level is sensed, preventing backflow from TK-23 into the vent system.	Active Engineered Control	Interlock fails to close tank feed valves on tank high level condition	High Chemical	3.14.1.3	A
			OCB Dryer/Calciner			
[redacted]	Rotary valve will not activate until the container-in-position proximity switch is activated.	Active Engineered Control	Interlock allows rotary valve to be operated without a container in the proper position	High Criticality	Spill-6	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Central vacuum system blower will not activate until the lid down sensor is activated.	Active Engineered Control	Interlock allows central vacuum system blower to be operated without barrel lid in proper position	High Criticality	Spill-6	A
[redacted]	Operator responds to calciner high pressure alarm on CCS, preventing release of calciner off-gases to the room.	Enhanced Administrative Control	Operator does not respond to high pressure alarm such that calciner off-gases vent to room or alarm does not actuate on high pressure condition	High and Intermediate Chemical	5.1.5.2, 5.3.1.1, 5.12.1.1, 6.1.3.1, 6.1.5.1, 6.1.6.1, 6.1.7.1, 6.1.11.1, 6.1.12.1, 6.1.13.1, 6.2.2.1, 6.2.3.1, 6.2.4.1, 6.2.5.5, 6.12.2.1, 7.1.3.5, 7.18.2.2, 7.18.2.5, 7.19.3.4, 7.19.3.7 FHA Fire # 7	A
[redacted]	Calciner is shut down when high pressure is sensed, preventing release of calciner off-gases to the room.	Active Engineered Control	Interlock fails to shut down calciner on high pressure condition	High and Intermediate Chemical	5.1.5.2, 5.3.1.1, 5.12.1.1, 6.1.3.1, 6.1.5.1, 6.1.6.1, 6.1.7.1, 6.1.11.1, 6.1.12.1, 6.1.13.1, 6.2.2.1, 6.2.3.1, 6.2.4.1, 6.2.5.5, 6.12.2.1, 7.1.3.5, 7.18.2.2, 7.18.2.5, 7.19.3.4, 7.19.3.7	A
OCB Uranium Recovery						
[redacted]	Overflow line for Tank 41- provides protection against backflow to unfavorable geometry utility supply tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line is plugged during operation or an unfavorable geometry container is beneath the overflow line	High Criticality	Backflow-1 Spill-1	A
[redacted]	*Overflow line for Tank 46 - provides protection* against backflow to unfavorable geometry utility supply tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line is plugged during operation or an unfavorable geometry container is beneath the overflow line	High Criticality	Backflow-1 Spill-1	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Overflow line for Tank 47B - provides protection against backflow to unfavorable geometry utility supply tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line is plugged during operation or an unfavorable geometry container is beneath the overflow line	High Criticality	Backflow-1 Spill-1	A
[redacted]	DI Water header valve closes when low water pressure is sensed by pressure indicator transmitter preventing backflow into the DI Water supply tanks.	Active Engineered Control	Interlock fails to close DIW header isolation valve on DIW header low pressure condition	High Criticality	Backflow-2	A
[redacted]	Dilute nitric acid header valve closes when low nitric acid pressure is sensed by pressure indicator transmitter preventing backflow into the dilute nitric acid supply tanks.	Active Engineered Control	Interlock fails to close DNA header isolation valve on DNA header low pressure condition	High Criticality	Backflow-2	A
[redacted]	Ammonium hydroxide header valve closes when low ammonium hydroxide pressure is sensed by pressure indicator transmitter preventing backflow into the ammonium hydroxide supply tanks.	Active Engineered Control	Interlock fails to close ammonium hydroxide header isolation valve on ammonium hydroxide header low pressure condition	High Criticality	Backflow-2	A
[redacted]	Operator responds to TK-40 high level alarm, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Enhanced Administrative Control	Operator does not respond to tank high level alarm such that a tank overflow occurs or alarm does not actuate on high level condition	High Chemical	17.1.1.1, 17.1.3.1, 17.3.1.1, 17.8.2.1, 17.14.2.1	A
[redacted]	Centrifuge feed valve closes when TK-40 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to close centrifuge feed valve on tank high level condition	High Chemical	17.1.1.1, 17.1.3.1, 17.3.1.1, 17.8.2.1, 17.14.2.1	A
[redacted]	Operator responds to TK-41 high level alarm, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Enhanced Administrative Control	Operator does not respond to tank high level alarm such that a tank overflow occurs or alarm does not actuate on high level condition	High Chemical	18.14.2.1, 18.14.2.2	A
[redacted]	Feed valves close when TK-41 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to close tank feed valves on tank high level condition	High Chemical	18.14.2.1, 18.14.2.2	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Operator responds to TK-43 high level alarm, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Enhanced Administrative Control	Operator does not respond to tank high level alarm such that a tank overflow occurs or alarm does not actuate on high level condition	High Chemical	20.1.1.1, 20.1.4.1, 20.3.1.1, 20.8.2.1, 20.14.2.1	A
[redacted]	Feed valves close when TK-43 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to close tank feed valves on tank high level condition	High Chemical	20.1.1.1, 20.1.4.1, 20.3.1.1, 20.8.2.1, 20.14.2.1	A
[redacted]	Operator responds to TK-47B high level alarm, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Enhanced Administrative Control	Operator does not respond to tank high level alarm such that a tank overflow occurs or alarm does not actuate on high level condition	High Chemical	23.3.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	A
[redacted]	Feed valves close when TK-47B high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to close tank feed valves on tank high level condition	High Chemical	23.3.1.1, 23.8.2.1, 23.14.1.1, 23.14.2.1	A
[redacted]	Operator responds to P-40 pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	17.1.7.1	A
[redacted]	Operator responds to P-41 pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	18.1.7.1	A
[redacted]	Operator responds to P-43 pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	20.1.6.1	A
[redacted]	Operator responds to P-47B pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	23.1.5.1	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Pump recirculation line for P-40 provides a flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	17.1.7.1	A
[redacted]	Pump recirculation line for P-41 provides a flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	18.1.7.1	A
[redacted]	Pump recirculation line for P-43 provides a flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	20.1.6.1	A
[redacted]	Pump recirculation line for P-47B provides a flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	23.1.5.1	A
OCB Oxide Blending						
[redacted]	Double roof over OCB moderation controlled area - prevents water (weather) from entering the moderation controlled area	Passive Engineered Control	Roof leaks resulting in greater than 15.8 liters of water into OCB moderation controlled area	High Criticality	Scenario 1.1a	A
[redacted]	Walls, barriers, dikes, raised floors, sealing around penetrations, no liquid-bearing lines - prevent liquids inside the OCB from entering the moderation controlled area	Passive Engineered Control	Greater than 15.8 liters of liquids enter OCB moderation controlled area	High Criticality	Scenario 1.1b	A
[redacted]	Posting at every entrance to the moderation controlled area: "NO WATER ALLOWED PAST THIS POINT." Prevents greater than 15.8 liters of water from being brought into the moderation controlled area.	Administrative Control	Greater than 15.8 liters of water enters moderation controlled area and is unattended or is spilled in violation of posted warnings	High Criticality	Scenario 1.1c	A
[redacted]	Posting at every entrance to the moderation controlled area: "WATER SHALL NOT BE USED TO FIGHT FIRES INSIDE THE MODCON AREA." Prevents greater than 15.8 liters of water from being brought into the moderation controlled area.	Administrative Control	Greater than 15.8 liters of water enters moderation controlled area as a result of fire fighting in violation of posted warnings	High Criticality	Scenario 1.1d	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Vessels, pipes, flanges and valves in the blending system and the air intake line for the vacuum transfer system are designed to prevent any liquid inside the moderation controlled area from entering the oxide blending system.	Passive Engineered Control	Vessels, pipes, flanges and valves in the blending system and the air intake line for the vacuum transfer system fail to prevent liquid from entering the oxide blending system	High Criticality	Scenario 1.1.a Scenario 1.1.b Scenario 1.1c Scenario 1.1e Scenario 1.4a	A
[redacted]	Posting at every entrance to the moderation controlled area: "COMBUSTIBLE ITEMS SHALL NOT BE STORED INSIDE THE MODCON AREA." Prevents a large fire, by reducing the combustible loading in the moderation controlled area.	Administrative Control	Combustible materials are stored in moderation controlled area in violation of posted warnings	High Criticality	Scenario 1.1.d	A
[redacted]	Calciner moisture analyzer - detects wet powder discharged from the calciner – interlocked with FV-33D/34D and B-35 to prevent discharge of wet powder from V-33/V34, and subsequent vacuum transfer to unfavorable geometry vessel.	Active Engineered Control	Interlock fails to de-energize discharge rotary valves and vacuum transfer blower on calciner discharge powder high moisture condition	High Criticality	Scenario 1.2 Scenario 1.3	A
[redacted]	Vessel V-33/V-34 moisture analyzers - detect wet powder inside V-33/V-34 - interlocked with FV-33D/34D and FV-33D1/34D1 to prevent the discharge of wet powder from V-33/V34, and subsequent vacuum transfer to unfavorable geometry vessel.	Active Engineered Control	Interlock fails to de-energize discharge rotary valves and vacuum transfer isolation valves on powder high moisture condition	High Criticality	Scenario 1.2 Scenario 1.3 Scenario 1.4a Scenario 1.1e	A
[redacted]	Operator must replace vacuum transfer vessel with favorable geometry collection container, and completely empty V-33 or V-34. Ensures that wet powder is only transferred into a favorable geometry container.	Administrative Control	Wet powder is transferred into an unfavorable geometry container due to operator error	High Criticality	Scenario 1.3 Scenario 2.2	A
[redacted]	Vacuum transfer vessel proximity switch - detects presence of vacuum transfer vessel at transfer stations V-33D/34D – interlocked with FV-33D/34D - prevents discharge of wet powder from V-33/V34 unless favorable geometry collection container is in place.	Active Engineered Control	Interlock fails to prevent powder discharge to unfavorable geometry system on high moisture condition	High Criticality	Scenario 1.3	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Compressed air dryer system - removes residual moisture in compressed air supply - prevents water ingress into the moderation controlled area (hygrometer detects moisture in airline, and switches over to alternate desiccant vessel).	Active Engineered Control	Water enters moderation controlled area due to compressed air dryer system failure	High Criticality	Scenario 1.4a Scenario 1.4b	A
[redacted]	Operator may only load a maximum of 2500 kg of oxide powder into V-36. This mass of powder will contain less than 15.8 kg of water (at the allowed moisture limit of 5000 ppm).	Administrative Control	More than 2500 kg of oxide powder is loaded into V-36 blender	High Criticality	Scenario 1.9	A
[redacted]	When the blender contains more than 1000 kg of oxide powder, either: 1. blender arm and auger must be in operation OR 2. dry nitrogen purge must be flowing through blender Maintains moisture homogeneously mixed with powder, or removes evaporated moisture from blender.	Administrative Control	Blender arm and auger are not in operation and dry nitrogen purge is not flowing through blender when more than 1000 kg of oxide powder are in blender	High Criticality	Scenario 1.9	A
[redacted]	V-33D/V-34D/V-36D interlocks - prevent the discharge of powder from V-33, V-34 or V-36, unless the receiving vessel is in place, connected and sealed.	Active Engineered Control	Interlock fails to prevent oxide powder from being discharged from V-33, V-34, V-36 without the receiving vessel in place, connected and sealed	High Criticality	Scenario 2.1 Scenario 2.2	A
[redacted]	Operator attendance at V-33D/34D is required when discharging wet powder into the favorable geometry collection container. Operator will stop rotary discharge valve if a powder spill is observed. This minimizes the mass of powder spilled.	Administrative Control	Excessive oxide powder spill occurs due to operator not being present at V-33D/34D when discharging	High Criticality	Scenario 2.2	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Blender pressure indication warns operator of upset condition	Administrative Control	Operator does not respond to pressure indication such that blender over-pressurization occurs	High Radiological	12.1.10.1, 12.1.9.1, 12.3.3.1, 12.3.5.2, 12.3.8.1	A
[redacted]	Vented vessel (blender)	Passive Engineering Control	Blender vent line plugged during operation	High Radiological	12.1.10.1, 12.1.8.1, 12.3.5.2, 12.3.8.1	A
[redacted]	Stainless steel material of construction (blender)	Passive Engineering Control	Material of construction not stainless steel	High Radiological	12.1.8.1, 12.1.9.1, 12.3.3.1	A
[redacted]	Vented vessel (hopper)	Passive Engineering Control	Hopper vent line plugged during operation	Intermediate Radiological	12.3.2.1	B
			OCB Dissolution			
[redacted]	Overflow line for Tank 76R - provides protection against backflow to unfavorable geometry utility supply tanks and chemical makeup tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line plugged during operation	High Criticality	4.1.1 4.1.5	A
[redacted]	Overflow line for Tank 70 - provides protection against backflow to unfavorable geometry utility supply tanks and chemical makeup tanks - designed to prevent placing an unfavorable geometry container beneath.	Passive Engineered Control	Tank overflow line plugged during operation	High Criticality	4.1.1 4.1.5	A
[redacted]	Secondary heat exchanger is made of proper materials of construction so that it meets ASME codes for use in system to ensure it will be reliable	Passive Engineered Control	Heat exchanger leak resulting in uranium contamination of cooling water system	High Criticality	4.1.4	A
[redacted]	Conductivity meter – monitors cooling water between primary and secondary heat exchangers – interlocked with LEU solution pump to prevent the potential for LEU to enter the cooling water supply system.	Active Engineered Control	Interlock fails to shut down *dissolver receiver tank pump* on cooling water high conductivity condition	High Criticality	4.1.4	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Enrichment monitor interlock - disables crane operation if enriched material is present in the natural enclosure – prevents LEU addition to natural dissolution system.	Active Engineered Control	Interlock fails to disable bridge crane if enriched material is sensed	High Criticality and Chemical	4.1.6 38.7.1.2	A
[redacted]	Proximity switch interlock - disables crane operation if 55-gallon drum is not detected - prevents LEU addition to natural dissolution system.	Active Engineered Control	Interlock fails to disable bridge crane if 55-gallon drum is not detected	High Criticality	4.1.6	A
[redacted]	Translucent off-gas line between V-77and TK-76R – prevents plugs and potential backflow to natural dissolution system	Passive Engineered Control	Off-gas line plugged during operation	High Criticality	4.1.5	A
[redacted]	Operator verifies material is added to dissolver to ensure correct material is used - prevents addition of LEU oxide.	Administrative Control	LEU oxide is added to natural dissolution system due to operator error	High Chemical	38.7.1.2	A
[redacted]	Operator responds to TK-76R high level alarm, preventing overflow of tank and venting of acid fumes through overflow.	Enhanced Administrative Control	Operator does not respond to tank high level alarm such that a tank overflow occurs or alarm does not actuate on high level condition	High Chemical	40.3.1.1, 40.3.2.4	A
[redacted]	Powder feeder de-energizes, and DIW and concentrated nitric acid valves close when TK-76A high level is sensed, preventing overflow of TK-76R (cascade from TK-76A to TK-76B to TK-76R) and venting of acid fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to de-energize powder feeder and close DIW and CNA supply valves on TK-76R high level condition	High Chemical	40.3.1.1, 40.3.2.4	A
[redacted]	Operator responds to TK-76A high temperature alarm, preventing damage to tank and release of acid fumes.	Enhanced Administrative Control	Operator does not respond to tank high temperature alarm such that tank damage occurs or alarm does not actuate on high temperature condition	High Chemical	40.11.1.1.A	A
[redacted]	Operator responds to TK-76B high temperature alarm, preventing damage to tank and release of acid fumes.	Enhanced Administrative Control	Operator does not respond to tank high temperature alarm such that tank damage occurs or alarm does not actuate on high temperature condition	High Chemical	40.11.1.1.A, 40.11.1.1.B	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Operator responds to TK-76R high temperature alarm, preventing damage to tank and release of acid fumes.	Enhanced Administrative Control	Operator does not respond to tank high temperature alarm such that tank damage occurs or alarm does not actuate on high temperature condition	High Chemical	40.11.1.1.B	A
[redacted]	Operator responds to V-77 high level alarm, preventing the venting of acid fumes from vessel through tank overflow lines.	Enhanced Administrative Control	Operator does not respond to V-77 high level alarm such that an overflow occurs or alarm does not actuate on high level condition	High Chemical	43.1.3.1	A
[redacted]	Powder feeder is de-energized, and DIW and nitric acid valves are maintained closed if V-77 high or low differential pressure condition occurs.	Active Engineered Control	Interlock fails to de-energize powder feeder and close DIW and CNA supply valves with V-77 high or low differential pressure condition	High Chemical	43.18.1.1 43.1.3.1, 43.1.8.1, 43.5.3.1	A
[redacted]	Powder feeder is de-energized, and DIW and nitric acid valves are maintained closed if V-38A high or low differential pressure condition occurs.	Active Engineered Control	Interlock fails to de-energize powder feeder and close DIW and CNA supply valves with V-38A high or low differential pressure condition	High Chemical	43.18.1.1	A
			OCB Ventilation			
[redacted]	A HEPA filter shall be installed between the favorable geometry and unfavorable geometry sections of the ventilation ductwork. A differential pressure indicator shall be installed across each of the HEPA filters to ensure the HEPA is installed.	Passive Engineered Control	HEPA filter not installed during operation	High Criticality	4.1.1.2	A
[redacted]	Periodic NDA scanning of the process ventilation system (ductwork and filters) for accumulation of uranium, which, if found, is cleaned out if the accumulation equals or exceeds the threshold limit.	Administrative Control	Scanning not performed in accordance with NDA procedures or cleanout not performed if threshold limit is exceeded	High Criticality	4.1.1.1	A
[redacted]	Condensate drains are installed at the local low points and specific listed places in the ventilation ductwork to drain solution from the ventilation ductwork. The drains are checked periodically and drained if solution is present.	Passive Engineered Control	Drain lines are plugged, resulting in solution accumulating in unfavorable geometry ductwork or Tank TK-70	High Criticality	4.1.1.1, 4.1.1.2 4.1.1.3.1, 4.1.1.3.2 4.1.1.3.3, 4.1.1.3.4 4.1.2.5	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Tank TK-78 overflow must be present and operational to drain overflowing solution from TK-78 prior to uranium-bearing solutions entering the DIW supply line to TK-78.	Passive Engineered Control	Tank overflow line is plugged during operation	High Criticality	4.1.2.1	A
[redacted]	DIW supply line elevation must be higher than scrubber V-38A and V-38B input ventilation lines.	Passive Engineered Control	DIW supply line elevation is not higher than scrubber V-38A and V-38B input ventilation lines, resulting in backflow of uranium into unfavorable geometry DIW supply system	High Criticality	4.1.2.2 4.1.2.3	A
[redacted]	DIW supply line elevation must be higher than the off-gas ventilation line from scrubber V-38A.	Passive Engineered Control	DIW supply line elevation is not higher than the off-gas ventilation line from scrubber V-38A, resulting in backflow of uranium into unfavorable geometry DIW supply system	High Criticality	4.1.2.2	A
[redacted]	Compressed air supply line elevation must be higher than the scrubber V-77 input ventilation lines.	Passive Engineered Control	Compressed air supply line elevation is not higher than the scrubber V-77 input ventilation lines, resulting in backflow of uranium into unfavorable geometry compressed air supply system	High Criticality	4.1.2.4	A
[redacted]	Compressed air supply line elevation must be higher than the off-gas ventilation line from scrubber V-77	Passive Engineered Control	Compressed air supply line elevation is not higher than the off-gas ventilation line from scrubber V-77, resulting in backflow of uranium into unfavorable geometry compressed air supply system	High Criticality	4.1.2.4	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	The off-gas lines from scrubber V-38A and the base POG tie into an open bottomed, vertical section of ventilation ductwork, which drains solution from an overflowing scrubber onto the floor.	Passive Engineered Control	Off-gas lines from scrubber V-38A and the base POG do not tie into an open bottomed, vertical section of ventilation ductwork, resulting in solution entering unfavorable geometry ductwork	High Criticality	4.1.1.3.1 4.1.1.3.2	A
[redacted]	Second, independent condensate drains that are installed at specific listed places in the ventilation ductwork to drain solution from the ventilation ductwork. The drains are checked periodically and drained if solution is present.	Passive Engineered Control	Drain lines are not installed or are not inspected, resulting in solution entering unfavorable geometry ductwork or Tank TK-70	High Criticality	4.1.1.3.3, 4.1.1.3.4 4.1.2.5	A
[redacted]	DIW supply line elevation must be higher than the condensate drain on off-gas ventilation line from scrubber V-38B.	Passive Engineered Control	DIW supply line elevation is not higher than the condensate drain on off-gas ventilation line from scrubber V-38B, resulting in backflow of uranium into unfavorable geometry DIW supply system	High Criticality	4.1.2.3	A
[redacted]	Operator responds to V-77 high/low differential pressure alarm, preventing the venting of acid fumes from vessel through tank overflow lines.	Enhanced Administrative Control	Operator does not respond to V-77 high/low differential alarm such that acid fumes are vented through tank overflow line or alarm does not actuate on high high/low differential pressure condition	High Chemical	43.1.8.1, 43.5.3.1	A
[redacted]	Operator responds to Tank TK-38 high level alarm, preventing tank overflow and release of chemical fumes to the room.	Enhanced Administrative Control	Operator does not respond to high level alarm such that a tank overflow occurs or alarm fails to actuate on high level condition	High Chemical	9.1.1.1	A
[redacted]	Tank TK-38 feed valves close when high level is sensed, preventing backflow from TK-38 into the vent system.	Active Engineered Control	Interlock fails to isolate tank feed flow on tank high level condition	High Chemical	9.1.1.1	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Operator responds to P-38 pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	9.1.2.2	A
[redacted]	Pump recirculation line for P-38 provides flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	9.1.2.2	A
[redacted]	Condensate tank drain valve is capped/plugged, preventing release of chemical liquid or fumes to the room.	Passive Engineered Control	Condensate tank drain valve is not capped/plugged, resulting in release of chemical liquid or fumes to the room	High Chemical	9.8.1.1	A
[redacted]	Operating procedures and training prevent improper valve operation.	Administrative Control	Release of chemical liquid or fumes to the room due to operator error	High Chemical	9.8.1.1	A
			EPB Ammonia Recovery/Liquid Waste			
[redacted]	Uranium analyzer is positioned on the IX effluent discharge line and is used to provide uranium concentration to an independent controller. Upon detection of uranium in excess of 50-ppm in the IX effluent, the controller positions a three-way valve to route IX column effluent to the IX Feed Tank (recycle path), instead of the Ammonia Recovery Receipt Tank (effluent path). In addition, a block and bleed valve arrangement in the effluent discharge line is activated.	Active Engineered Control	Interlock fails to isolate flow from IX column to AR Receipt tank on high uranium concentration condition	High Criticality	EAL-Excess Uranium-1 EAL-Excess Uranium-2	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	A second uranium analyzer is positioned on the IX effluent discharge line and is used to provide uranium concentration to an independent controller. Upon detection of uranium in excess of 50-ppm in the IX effluent, the controller positions a three-way valve to route IX column effluent to the IX Feed Tank (recycle path), instead of the Ammonia Recovery Receipt Tank (effluent path). In addition, a block and bleed valve arrangement in the effluent discharge line is activated.	Active Engineered Control	Interlock fails to isolate flow from IX column to AR Receipt tank on high uranium concentration condition	High Criticality	EAL-Excess Uranium-1 EAL-Excess Uranium-2	A
[redacted]	NDA scanning is required for all unfavorable geometry vessels in the EPB to detect any potential uranium accumulation. The scan shall be made on the bottom of the unfavorable geometry vessel.	Administrative Control	Scanning not performed in accordance with NDA procedures	High Criticality	EAL-Excess Uranium-2	A
[redacted]	Laboratory analysis is performed on a composite sample taken throughout the week from the AR receipt tank (TK-50) feed line (from the OCB IX system) to determine the amount of uranium entering the EPB. Over the same time period, laboratory analysis is performed on the solid waste exiting the EPB to determine the uranium amount leaving the EPB. The difference between the uranium entering and exiting the EPB is the uranium mass hold up in the EPB. A cumulative uranium mass hold up is maintained for the EPB. If the cumulative hold up becomes greater than 32 kg, tank inspections and NDA scans on EPB equipment other than tanks must be conducted to locate the uranium for clean-out.	Administrative Control	Mass hold up in the EPB exceeds 32 kg and system cleanout is not performed	High Criticality	EAL-Excess Uranium-2	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Operator responds to TK-54 high level alarm, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Enhanced Administrative Control	Operator does not respond to high level alarm such that a tank overflow occurs or alarm fails to actuate on high level condition	High Chemical	27.1.3.1	A
[redacted]	Feed valve closes when TK-54 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to close tank feed valves on tank high level condition	High Chemical	27.1.3.1	A
[redacted]	Operator responds to P-50 pump casing high temperature alarm, preventing ammonium nitrate detonation.	Enhanced Administrative Control	Pump casing temperature exceeds 200°F because of alarm failure or operator inattention	High Chemical	25.1.1.1	A
[redacted]	Pump recirculation line for P-50 provides a flow path to prevent pump dead-head condition, preventing ammonium nitrate detonation.	Passive Engineered Control	Pump recirculation path is blocked while pump is operating on ammonium nitrate solution	High Chemical	25.1.1.1	A
[redacted]	Stripper steam supply is shut off when high pressure switch senses high pressure in the stripper, preventing over-pressurization of column V-52.	Active Engineered Control	Interlock fails to close steam supply to stripper on stripper high pressure condition	High Chemical	27.1.4.1	A
[redacted]	Operator responds to V-52 high pressure alarm, preventing over-pressurization of stripper column.	Enhanced Administrative Control:	Operator does not respond to high pressure alarm such that a stripper over-pressurization occurs or alarm fails to actuate on high pressure condition	High Chemical	27.1.4.1	A
[redacted]	Operator responds to low DIW flow to V-59 alarm, preventing release of high concentration ammonia fumes to the environment.	Administrative Control	Operator does not respond to DIW low flow alarm such that a high concentration of ammonia fumes are released to the environment or alarm fails to actuate on a low DIW flow condition	High Chemical	27.1.5.1	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Operator responds to ammonia scrubber exhaust stack high ammonia concentration alarm, preventing release of high concentration ammonia fumes to the environment.	Enhanced Administrative Control	Operator does not respond to exhaust stack high ammonia concentration alarm such that a high concentration of ammonia fumes are released to the environment or alarm fails to actuate on a high ammonia concentration condition	High Chemical	27.1.5.1	A
[redacted]	Procedural warning that V-59 liquid discharge line manual isolation valve is to remain open during scrubber operation.	Administrative Control	Valve is closed during scrubber operation	High Chemical	27.1.6.1	A
[redacted]	V-59 liquid discharge line manual isolation valve has installed tamper seal.	Administrative Control	Valve does not have tamper seal properly installed during operation	High Chemical	27.1.6.1	A
[redacted]	Over-pressurization of TK-AH and TK-54 prevented by venting through V-59.	Passive Engineered Control	Tank vent line is plugged during operation	High Chemical	27.9.1.1, 27.9.1.2	A
[redacted]	Operator responds to TK-54 high pressure alarm, preventing tank/header over-pressurization.	Enhanced Administrative Control	Operator does not respond to high pressure alarm such that a tank/header over-pressurization occurs or alarm fails to actuate on high pressure condition	High Chemical	27.9.1.1, 27.9.1.2	A
[redacted]	Treated effluent and recycle valves close when TK-50 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to isolate tank feed flow on tank high level condition	Intermediate Chemical	25.1.2.1.A	B
[redacted]	Receipt tank discharge valve and sodium hydroxide supply valve close when TK-51 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to isolate tank feed flow on tank high level condition	Intermediate Chemical	25.1.2.1.B	B

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Feed tank discharge valve closes on shutdown or failure of P-51, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to isolate tank discharge flow on tank high level condition	Intermediate Chemical	25.4.2.1	B
[redacted]	TK-50 overflow line provides flow path to prevent tank over-pressurization.	Passive Engineered Control	Tank overflow line is plugged during operation	Intermediate Chemical	27.9.1.3	B
	Bulk Chemicals – Ammonium Hydroxide					
[redacted]	Operating procedures and training ensure that ammonium hydroxide pump recirculation line valve remains open during pump operation.	Administrative Control	Valve is closed during pump operation	High Chemical	47.1.5.2	A
[redacted]	TK-AH pump recirculation line manual isolation valve has installed tamper seal.	Administrative Control	Valve does not have tamper seal properly installed during operation	High Chemical	47.1.5.2	A
[redacted]	Operator responds to TK-AH high level alarm, preventing the venting of ammonium hydroxide liquid and fumes through tank overflow line.	Enhanced Administrative Control	Operator does not respond to high tank level alarm such that venting of ammonium hydroxide fumes occurs or alarm does not actuate on high level condition	High Chemical	47.3.1.1	A
[redacted]	Operating procedures and training prevent operator from allowing vendor to off load to tank unless adequate volume is available for product.	Administrative Control	Spill occurs and ammonia fumes are released due to operator error	High Chemical	47.3.1.1	A
	Bulk Chemicals – Dilute Nitric Acid					
[redacted]	Dilute nitric acid header isolation valve closes when high acid concentration is sensed, preventing flow of concentrated nitric acid into the dilute nitric acid header.	Active Engineered Control	Interlock fails to close DNA header isolation valve on high acid concentration condition	High Chemical	49.1.7.1	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Operator will initiate and monitor dilute acid makeup process in accordance with approved operating procedures, preventing production of dilute nitric acid concentrations above safe levels.	Administrative Control	Unsafe dilute acid concentrations are produced due to operator error	High Chemical	49.1.7.1	A
			Bulk Chemicals – Concentrated Nitric Acid			
[redacted]	Operator responds to TK-CNA high level alarm, preventing the venting of acid liquid and fumes through tank overflow line.	Enhanced Administrative Control	Operator does not respond to high level alarm such that a tank overflow occurs or alarm fails to actuate on high level condition	Intermediate Chemical	49.1.11.1	B
[redacted]	Operating procedures and training ensure that concentrated nitric acid pump recirculation line valve remains open during pump operation.	Administrative Control	Valve is closed during pump operation	Intermediate Chemical	49.1.2.1	B
			Hydrogen Supply System			
[redacted]	*Hydrogen supply valve interlocked* closed if high oxygen content is detected in the calciner off gas, preventing build up of explosive atmosphere in equipment	Active Engineering Control	Interlock fails to close hydrogen supply valve on high oxygen concentration condition	High Chemical and Radiological	FHA Fire # 7 Explosion 1	A
[redacted]	Hydrogen supply valve interlocked closed if high hydrogen content is detected in the exhaust ventilation, preventing build up of explosive atmosphere in equipment	Active Engineering Control	Interlock fails to close hydrogen supply valve on exhaust ventilation high hydrogen concentration condition	High Chemical and Radiological	FHA Fire # 9 Explosion 3	A
[redacted]	Hydrogen supply valve interlocked closed if low dilution air flow is detected, preventing build up of explosive atmosphere in equipment	Active Engineering Control	Interlock fails to close hydrogen supply valve on low dilution air flow condition	High Chemical and Radiological	FHA Fire # 9 Explosion 3	A
[redacted]	Hydrogen supply valve interlocked closed if high/low hydrogen pressure is detected, preventing build up of explosive atmosphere in equipment.	Active Engineering Control	Interlock fails to close hydrogen supply valve on high/low hydrogen pressure condition	High Radiological	Explosion 1 Explosion 2 Explosion 4	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Vacuum-pressure system blower	Active Engineering Control	Vacuum-pressure system blower fails to maintain negative pressure on system	High Radiological	Explosion 2 Explosion 4	A
			Drum Handling			
[redacted]	Drum handling operations are performed in a hood, protecting operators from harmful airborne contamination	Passive Engineering Control	Operators are exposed to airborne contamination due to failure of containment hood	Intermediate Chemical	38.25.1.1	B
			OCB General			
[redacted]	Unfavorable geometry containers are restricted from the OCB Areas (all areas except NUN Dissolution area).	Administrative Control	Unfavorable geometry container is in a restricted OCB area	High Criticality	All areas except NUN Dissolution area	A
[redacted]	Containers for spill cleanup in OCB are limited to favorable geometry (all areas except NUN Dissolution area).	Administrative Control	Unfavorable geometry container is used for spill cleanup in a restricted OCB area	High Criticality	All areas except NUN Dissolution area	A
[redacted]	Containers in the OCB Conversion Area may not be left open and unattended (all areas except NUN Dissolution area).	Administrative Control	Container is left open and unattended in a restricted OCB area	High Criticality	All areas except NUN Dissolution area	A
[redacted]	DI Water supply valve closes when low water pressure is sensed by pressure indicator transmitter preventing backflow into the DI Water supply tanks.	Active Engineered Control	Interlock fails to close DIW supply valve on DIW low header pressure condition	High Criticality	Backflow-1 Backflow-2 Backflow-3 Backflow-5 Scenario 4.1.1 4.1.2.1	A
[redacted]	Dilute nitric acid supply valve closes when low nitric acid pressure is sensed by pressure indicator transmitter preventing backflow into the dilute nitric acid supply tanks.	Active Engineered Control	Interlock fails to close DNA supply valve on DNA low header pressure condition	High Criticality	Backflow-1 Backflow-2 Backflow-4 4.1.1	A
[redacted]	Ammonium hydroxide supply valve closes when low ammonium hydroxide pressure is sensed by pressure indicator transmitter preventing backflow into the ammonium hydroxide supply tanks.	Active Engineered Control	Interlock fails to close ammonium hydroxide supply valve on ammonium hydroxide low header pressure condition	High Criticality	Backflow-1 Backflow-2 Backflow-4 Backflow-5	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Process vessels and piping are fabricated using materials of construction compatible with process fluids.	Passive Engineered Control	Process vessels or piping are fabricated using incompatible materials of construction	High and Intermediate Chemical	2.24.1.1, 7.17.9.2, 9.17.4.1, 9.17.5.1, 9.17.6.1, 17.17.1.1, 20.17.1.1, 21.1.1.1, 23.17.1.1,25.21.1.2 27.17.1.1, 40.6.2.3, 43.17.2.1, 7.16.1.1, 49.21.2.1, 5.21.1.1, 40.25.5.1, 9.21.3.2 49.21.3.2	A
[redacted]	Periodic inspection and maintenance program ensures equipment is properly maintained and prevents exposure to chemical liquids or fumes due to pipe or vessel corrosion or failure.	Administrative Control	Piping or vessel corrosion results in chemical exposures	High and Intermediate Chemical	2.24.1.1, 7.17.9.2, 9.17.4.1, 9.17.5.1, 9.17.6.1, 17.17.1.1, 20.17.1.1, 21.1.1.1, 23.17.1.1, 5.21.1.2, 27.17.1.1, 40.6.2.3, 43.17.2.1, 7.16.1.1, 49.21.2.1, 5.21.1.1, 40.25.5.1, 9.21.3.2 49.21.3.2	A
[redacted]	Combustible loading program restricts the amount of potentially combustible material in the operating spaces of the OCB	Administrative Control	Fire occurs due to excessive combustibles present in OCB	High Chemical	FHA Fire # 4 FHA Fire # 5 FHA Fire # 6	A
[redacted]	Fire protection test, maintenance and inspection activities detect and remove potential combustibles from the operating spaces of the OCB	Administrative Control	Fire occurs due to excessive combustibles present in OCB	High Chemical	FHA Fire # 4 FHA Fire # 5 FHA Fire # 6	A
[redacted]	The OCB and EPB are designed to meet the seismic load resistance as specified in the 1999 Standard Building Code.	Passive Engineered Control	Building incorrectly designed, installed, or modified so that it does not meet the code requirements	NA	NA	A
[redacted]	The UNB is designed to meet the wind load resistance as specified in the 1999 Standard Building Code.	Passive Engineered Control	Building incorrectly designed, installed, or modified so that it does not meet the code requirements	NA	NA	A

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Structures, systems, components, such as favorable geometry columns, dikes, floors, and piping that require configuration control.	Passive Engineered Control	Incorrectly designed, installed or modified such that controlled dimensions are not *maintained*	NA	NA	A

Note 1: The Central Control System (CCS) in the OCB/EPB is used as part of several active engineered and enhanced administrative controls. Appropriate management measures listed in Table 4.8 for active engineered controls will be applied to the CCS as a whole because individual components in the system cannot be isolated and treated separately.

Note 2: A formal calculation of each safety setpoint will be performed for active engineered controls and enhanced administrative controls. This calculation will be documented in the equipment file for each applicable IROFS. Calculations will follow good engineering practice, which is advised by, but not dictated by standards such as ISA-S67.04, which is intended for application in nuclear power plants (with their vastly higher safety risks).

6.2 BASELINE DESIGN CRITERIA FOR CREDITED IROFS

The Baseline Design Criteria specified in 10 CFR 70.64 are addressed for the OCB/EPB 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 OCB/EPB. 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 OCB/EPB. 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 6-2 and 6-3** 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 OCB/EPB.

Quality Standards and Records

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 of the OCB/EPB ISA Summary 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 materials 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

Natural phenomena are discussed in detail in Section 1 of the OCB/EPB 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 OCB/EPB baseline design threshold for each natural phenomena event is as follows:

Seismic	The OCB and EPB are designed and constructed to seismic zone IIC criteria as specified in Section 1607 of the 1999 Standard Building Code. The threshold return period for which the facility is designed and constructed to is 2E-3/yr. The Effective Peak Velocity Related Acceleration Coefficient Av and Peak Acceleration Coefficient Aa are defined as specified in Figures 1607.1.5A and 1607.1.5B of the Code respectively.
High Winds	The OCB and EPB are 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.
Flooding	The OCB and EPB are located above the 100-year flood plain base flood elevation threshold. As such, there is no physically credible accident scenario that could result in a flood of the facility.
Lightning	Lightning protection is installed in the OCB and EPB 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	There are no credible accident scenarios that result in an intermediate or high consequence event as a result of a direct tornado strike on OCB or EPB.

Code compliance in these cases is ensured by:

- Design drawings and specifications call out applicable code requirements.
- Suppliers and vendors will certify that supplied equipment and systems comply with the drawings and specifications, and other relevant codes. For instance, the building supplier provides certification that the building structure was designed to the Standard Building Code (SBC).
- Construction/installation will be per the design specifications by qualified contractors. For example, the building is being constructed by trained construction personnel; and the contractor will provide certification that the building was constructed per the design.
- Construction progress is reviewed frequently by qualified Framatome ANP engineering personnel.

- Multiple inspections are performed by the Town of Erwin inspectors as part of the Building Permit process (plumbing, electrical, building, etc.). A Certificate of Occupancy will be issued only when the last inspection has been completed satisfactorily.

- The internal Acceptance Test Procedures will have signoff/checklists that document the as-built verifications that the various installations meet code requirements, where applicable.

- Walkdowns of the facility will be conducted as part of the internal Operational Readiness Review process to ensure the building construction and equipment installation was completed properly.

- Future changes to the facility, structures, processes, systems, equipment, components, computer programs, procedures, etc. shall be processed 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.

Consideration of the effects of natural phenomena on OCB/EPB operations is included in Sections 1 and 4.2 of this report. Sections 1 and 4.2 include discussion of earthquake, tornado, flood, lightning, and high wind impacts on OCB/EPB operations. Engineering design requirements for all active and passive IROFS will include adequate protection from natural phenomena events. Seismic, wind, and lightning hazards are specifically addressed for OCB/EPB operations through implementation of code design requirements (Standard Building Code 1999, ASCE-97, NFPA-780).

In order to confirm that all natural phenomena hazards have been addressed for each passive and active engineered IROFS, engineering will use a spreadsheet as shown in Tables 6-2 and 6-3 to document the design considerations for each engineered IROFS.

Fire Protection

Section 2 of this report defines the fire protection features and systems for the OCB/EPB. These features are based on a comprehensive FHA performed for the OCB/EPB as part of the ISA process. Section 3 of this report identifies the fire hazards and protection systems for each process of OCB/EPB 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 protection of OCB/EPB operations from fires and explosions.

Environmental and Dynamic Effects

The OCB and EPB are 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 documentation.

Consideration and verification of environmental and dynamic effects will be documented for each engineered IROFS as shown in Tables 6-2 and 6-3.

Chemical Protection

Chemical safety is achieved through administrative as well as passive and active engineered controls. The proper handling, use, and storage of chemicals is addressed through procedures and Hazard Communication training. The ISA has evaluated any scenarios that could result in hazardous chemicals contacting or resulting in the dispersion of licensed material.

IROFS with the potential for contact with hazardous chemicals, are designed to maintain their safety function under normal or worst case chemical exposure conditions. Materials of construction are specified, along with initial verification and periodic inspection, to ensure that chemical exposure does not degrade the safety function of the IROFS. Chemical protection will also be designated and verified for each IROFS as shown in Tables 6-2 and 6-3.

Emergency Capability

(i) Licensed material and hazardous chemicals produced from licensed material;

The design basis for the planned measures at the BLEU Complex, which will control access to licensed material and hazardous chemicals produced from licensed materials are:

1. NRC Category III security requirements. These requirements are described in Chapter 2 of NFS' security plan, NFS-SEC-C3-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 BLEU 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 OCB and EPB meet 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 basis for the items addressed in the Emergency Plan to ensure control of the evacuation of on-site personnel is:

1. A criticality detection system in accordance with requirements of 10 CFR 70.24.
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 basis 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 Emergency Response Organization and support teams with appropriate expertise and experience. Regular training and exercises provided to the team members.
2. The emergency facilities, which support the BLEU Complex, 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 our selection of our 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 criticality and radiation accidents.
4. Hospitals equipped for radioactive contaminated persons
    a. Both JCMC and the local hospital, Unicoi County Hospital has a program, trained staff and equipment to respond to a radiation accident.

Utility Services

There is only one utility in the OCB and EPB that could be considered an "essential utility service" – the water supply to the fire suppression system. The "continued operation" of this system is assured because the water supply meets all relevant NFPA requirements for such a system. To enhance the reliability of the water supply for the sprinkler system, the water supply pressure to the fire suppression system will be monitored and will alarm in the CCS if the pressure drops below sprinkler system design requirements. In the event that pressure is lost, impairment procedures will be activated.

All other utilities, whether supplied from offsite (electricity, natural gas, etc.) or generated onsite (compressed air, DIW, etc.) are not considered "essential". Systems such as the fire alarm system and criticality monitors have dedicated sources of emergency power in the event power is lost. Accident scenarios related to the loss of primary and backup power and the effects on other service utilities have been evaluated. Further, the effect of loss of power on the effectiveness of IROFS was evaluated. No unsafe conditions were identified resulting from loss of power. The entire facility is designed fail safe so that loss of power causes control devices to fail into a safe state. Finally, fire detection systems, criticality monitors/alarms, and building evacuation alarms are located in areas where they should not be susceptible to damage.

Utility services for OCB/EPB operations are addressed in Section 2.3 of this report. Section 2.3 provides detailed descriptions of utility services required for OCB/EPB operations. The design considerations specified in Section 2.3 will provide for continued operation of essential utility services for OCB/EPB operations.

Inspection, Testing, and Maintenance

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. 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

All SNM operations in the OCB and EPB are designed with sufficient factors of safety to require at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible. This concept is known as the "double contingency principle." Whenever practicable, the effectiveness of the controls will be enhanced through diversity and redundancy of reliable barriers, and defense in depth.

Any changes to the criticality monitoring system are administered via the change management system referenced in Section 4.4. Criticality controls and Defense in Depth are evaluated for the OCB and EPB in the Nuclear Criticality Safety Evaluations (NCSEs).

Criticality safety evaluations are performed for each OCB/EPB 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. The required IROFS for protection from credible criticality events are identified in Table 6-1.

Instrumentation and Controls

Active engineered controls are used extensively for safety purposes in the OCB and EPB facility. Section 4.4 of the ISA Summary addresses the requirements for inspection, periodic functional checks, and maintenance to ensure the effectiveness of IROFS. This type of IROFS is typically implemented through the Central Control System (CCS). The CCS provides extensive internal diagnostic checks that will detect component failures and trigger alarms and in appropriate cases will send the outputs to a safe state. This is true for individual field instruments up through the controllers themselves and all communication links in between.

In general, equipment systems that will be used as enhanced administrative or active engineered control IROFS will have means for verification that key components of the IROFS are functional. Applicable information about monitoring each individual IROFS of these types will be contained in the ISA.

The design of IROFS listed in Tables 6-1 includes consideration of instrumentation and control systems to monitor and control the listed IROFS. The identified alarms, indications, etc., provide added assurance that IROFS will be available and reliable when needed.

Again, Tables 6-2 and Table 6-3 will be used to confirm and document that each engineered IROFS includes an appropriate level of instrumentation and controls.

Defense in Depth

- Preference for the selection of engineered controls over administrative controls to increase overall system reliability.
  Per the risk-based ISA process, as defined in NUREG-1520, risks are minimized by selecting the appropriate level of controls that will render each accident scenario that has a high consequence "highly unlikely". However, in general the following is the listed order of preference:
    - Passive Engineered Control (most preferred)
    - Active Engineered Control
    - Enhanced Administered Control
    - Administrative Control (least preferred)

  When used, administrative controls are appropriately enhanced through the use of postings, procedures, and computer programs that act as aids for the operator. In addition, appropriate safety margins are provided for administrative controls.

- Features that enhance safety by reducing challenges to items relied on for safety.

Defense in depth principles are addressed in OCB/EPB 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 OCB/EPB design to ensure that defense-in-depth is adequately addressed including preference for engineered controls over administrative controls and reduction of IROFS challenges.

Table 6-2
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
Valve-1	Close on loss of air	x	0	0	0	0	B	c	x	x

Table 6-3
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
Pas-A-1	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, whereas the chemical exposure levels are qualitatively identified in terms of worker or public health affects. Appendix A to Chapter 3 of NUREG 1520 provides quantitative chemical exposure levels in terms of ERPG or AEGL levels for each qualitative level in 10 CFR 70.61. This guidance will be used for chemical exposure levels in the OCB/EPB 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 OCB/EPB 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. For determining Intermediate and High chemical exposure levels to the worker from soluble uranium, DOE-STD-1136-2000, "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities", was used as a basis for exposures that could endanger life or lead to serious health effects.

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 ≥30 mg sol. U	≥ ERPG-3	≥ERPG-2
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	≥ ERPG-2 <ERPG-3	≥ERPG-1 <ERPG-2
Low	<Intermediate Levels	<Intermediate Levels	<Intermediate Levels	<Intermediate Levels

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 7-2
10 CFR 20, Appendix B (Table 2) Concentrations for OCB/EPB

Radionuclide	Table 2 Effluent Concentrations			5000 Times Table 2 Values		
	Solubility Class			Solubility Class		
	D	W	Y	D	W	Y
U-232	6.00E-13	5.00E-13	1.00E-14	3.00E-09	2.50E-09	5.00E-11
U-233	3.00E-12	1.00E-12	5.00E-14	1.50E-08	5.00E-09	2.50E-10
U-234	3.00E-12	1.00E-12	5.00E-14	1.50E-08	5.00E-09	2.50E-10
U-235	3.00E-12	1.00E-12	6.00E-14	1.50E-08	5.00E-09	3.00E-10
U-236	3.00E-12	1.00E-12	6.00E-14	1.50E-08	5.00E-09	3.00E-10
U-237	4.00E-09	2.00E-09	2.00E-09	2.00E-05	1.00E-05	1.00E-05
U-238	3.00E-12	1.00E-12	6.00E-14	1.50E-08	5.00E-09	3.00E-10
Tl-207	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Tl-208	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Tl-209	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Th-227	5.00E-13	5.00E-13	5.00E-13	2.50E-09	2.50E-09	2.50E-09
Th-228	3.00E-14	3.00E-14	2.00E-14	1.50E-10	1.50E-10	1.00E-10
Th-229	3.00E-15	3.00E-15	4.00E-15	1.50E-11	1.50E-11	2.00E-11
Th-230	2.00E-14	2.00E-14	3.00E-14	1.00E-10	1.00E-10	1.50E-10
Th-231	9.00E-09	9.00E-09	9.00E-09	4.50E-05	4.50E-05	4.50E-05
Th-232	4.00E-15	4.00E-15	6.00E-15	2.00E-11	2.00E-11	3.00E-11
Th-234	3.00E-10	3.00E-10	2.00E-10	1.50E-06	1.50E-06	1.00E-06
Tc-99	8.00E-09	9.00E-10	9.00E-10	4.00E-05	4.50E-06	4.50E-06
Sr-90	3.00E-11	6.00E-12	6.00E-12	1.50E-07	3.00E-08	3.00E-08
Sm-147	1.00E-13	1.00E-13	1.00E-13	5.00E-10	5.00E-10	5.00E-10
Ra-223	9.00E-13	9.00E-13	9.00E-13	4.50E-09	4.50E-09	4.50E-09
Ra-224	2.00E-12	2.00E-12	2.00E-12	1.00E-08	1.00E-08	1.00E-08
Ra-225	9.00E-13	9.00E-13	9.00E-13	4.50E-09	4.50E-09	4.50E-09
Ra-226	9.00E-13	9.00E-13	9.00E-13	4.50E-09	4.50E-09	4.50E-09
Ra-228	2.00E-12	2.00E-12	2.00E-12	1.00E-08	1.00E-08	1.00E-08
Pu-238	2.00E-14	2.00E-14	2.00E-14	1.00E-10	1.00E-10	1.00E-10
Pu-239	2.00E-14	2.00E-14	2.00E-14	1.00E-10	1.00E-10	1.00E-10
Pu-240	2.00E-14	2.00E-14	2.00E-14	1.00E-10	1.00E-10	1.00E-10
Pu-241	8.00E-13	8.00E-13	1.00E-12	4.00E-09	4.00E-09	5.00E-09
Po-210	9.00E-13	9.00E-13	9.00E-13	4.50E-09	4.50E-09	4.50E-09
Po-218	1.00E-15	1.00E-15	1.00E-15	5.00E-12	5.00E-12	5.00E-12
Pm-147	3.00E-10	3.00E-10	2.00E-10	1.50E-06	1.50E-06	1.00E-06
Pb-209	8.00E-08	8.00E-08	8.00E-08	4.00E-04	4.00E-04	4.00E-04
Pb-210	6.00E-13	6.00E-13	6.00E-13	3.00E-09	3.00E-09	3.00E-09
Pb-211	9.00E-10	9.00E-10	9.00E-10	4.50E-06	4.50E-06	4.50E-06

Radionuclide	Table 2 Effluent Concentrations			5000 Times Table 2 Values		
	Solubility Class			Solubility Class		
	D	W	Y	D	W	Y
Pb-212	5.00E-11	5.00E-11	5.00E-11	2.50E-07	2.50E-07	2.50E-07
Pb-214	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Pa-231	6.00E-15	6.00E-15	8.00E-15	3.00E-11	3.00E-11	4.00E-11
Pa-233	1.00E-09	1.00E-09	8.00E-10	5.00E-06	5.00E-06	4.00E-06
Pa-234	1.00E-08	1.00E-08	9.00E-09	5.00E-05	5.00E-05	4.50E-05
Pa-234m	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Np-237	1.00E-14	1.00E-14	1.00E-14	5.00E-11	5.00E-11	5.00E-11
Fr-221	1.00E-15	1.00E-15	1.00E-15	5.00E-12	5.00E-12	5.00E-12
Fr-223	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Eu-154	3.00E-11	3.00E-11	3.00E-11	1.50E-07	1.50E-07	1.50E-07
Cs-134	2.00E-10	2.00E-10	2.00E-10	1.00E-06	1.00E-06	1.00E-06
Cs-137	2.00E-10	2.00E-10	2.00E-10	1.00E-06	1.00E-06	1.00E-06
Bi-210	5.00E-10	4.00E-11	4.00E-11	2.50E-06	2.00E-07	2.00E-07
Bi-211	1.00E-15	1.00E-15	1.00E-15	5.00E-12	5.00E-12	5.00E-12
Bi-212	3.00E-10	4.00E-10	4.00E-10	1.50E-06	2.00E-06	2.00E-06
Bi-213	4.00E-10	5.00E-10	5.00E-10	2.00E-06	2.50E-06	2.50E-06
Bi-214	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Ba-137m	1.00E-09	1.00E-09	1.00E-09	5.00E-06	5.00E-06	5.00E-06
Am-241	2.00E-14	2.00E-14	2.00E-14	1.00E-10	1.00E-10	1.00E-10
Ac-225	7.00E-13	9.00E-13	9.00E-13	3.50E-09	4.50E-09	4.50E-09
Ac-227	1.00E-15	4.00E-15	6.00E-15	5.00E-12	2.00E-11	3.00E-11
Ac-228	2.00E-11	8.00E-11	6.00E-11	1.00E-07	4.00E-07	3.00E-07

When a DCF for a particular clearance class was not available, the following hierarchy was used. In the case when only one DCF was available it was used for all classes. If there was a value for W class but none for Y the W value was used for Y. If there was no value for W and/or Y, the class D value was used. If there wasn't a value for D but there was for W, the one for W was used.

Table 7-3
Chemical Exposure Standards for OCB/EPB

Chemical Name	Intermediate Consequence Public > ERPG-1 < ERPG-2	High Consequence Public > ERPG-2	Intermediate Consequence Worker > ERPG-2 < ERPG-3	High Consequence Worker > ERPG-3
Ammonia (NH_3)	≥ 25 ppm < 150 ppm	≥ 150 ppm	≥ 150 ppm <750 ppm	> 750 ppm
Hydrogen (H_2)	≥210,000 ppm < 350,000 ppm	≥ 350,000 ppm	≥ 350,000 ppm < 500,000 ppm	≥ 500,000 ppm
Nitric Acid, 60% (HNO_3)	> 1 ppm < 6 ppm	> 6 ppm	> 6 ppm < 78 ppm	> 78 ppm
Nitrogen (N_2)	> 210,000 ppm < 350,000 ppm	> 350,000 ppm	> 350,000 ppm < 500,000 ppm	> 500,000 ppm
NOX (NO,NO_2)	> 25 ppm	> 25 ppm	> 25 ppm < 100 ppm	> 100 ppm
Sodium Hydroxide, 50%	> 0.5 mg/m^3 < 5 mg/m^3	> 5 mg/m^3	> 5 mg/m^3 < 50 mg/m^3	> 50 mg/m^3
Sodium Nitrate	> 1 mg/m^3 < 7.5 mg/m^3	> 7.5 mg/m^3	> 7.5 mg/m^3 < 100 mg/m^3	> 100 mg/m^3
Uranium (soluble)*	N/A	≥ 30 mg	≥ 40 mg < 230 mg	≥ 230 mg

Note: All levels are based on TEEL values, except Ammonia, Nitric Acid, and Sodium Hydroxide which have established ERPG values
*The soluble Uranium exposure levels are based on DOE-STD-1136-2000, "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities". The standard defines 40 mg soluble uranium as the threshold for permanent renal damage, and ≥ 230 mg as the threshold for 50% lethality.

8.0 SOLE IROFS IN THE OCB/EPB

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 OCB/EPB

IROFS ID #	Safety Function Description	Type	Failure Description	Consequence Level	Accident Sequence	MM Level
[redacted]	Vented vessel (hopper)	Passive Engineering Control	Hopper vent line plugged during operation	Intermediate Radiological	12.3.2.1	B
[redacted]	Treated effluent and recycle valves close when TK-50 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to isolate tank feed flow on tank high level condition	Intermediate Chemical	25.1.2.1.A	B
[redacted]	Receipt tank discharge valve and sodium hydroxide supply valve close when TK-51 high level is sensed, preventing overflow of tank and venting of ammonia fumes through overflow or flow of liquid into vent piping.	Active Engineered Control	Interlock fails to isolate tank feed flow on tank high level condition	Intermediate Chemical	25.1.2.1.B	B
[redacted]	TK-50 overflow line provides flow path to prevent tank over-pressurization.	Passive Engineered Control	Tank overflow line is plugged during operation	Intermediate Chemical	27.9.1.3	B
[redacted]	Operator responds to TK-CNA high level alarm, preventing the venting of acid liquid and fumes through tank overflow line.	Enhanced Administrative Control	Operator does not respond to high level alarm such that a tank overflow occurs or alarm fails to actuate on high level condition	Intermediate Chemical	49.1.11.1	B
[redacted]	Operating procedures and training ensure that concentrated nitric acid pump recirculation line valve remains open during pump operation.	Administrative Control	Valve is closed during pump operation	Intermediate Chemical	49.1.2.1	B
[redacted]	Drum handling operations are performed in a hood, protecting operators from harmful airborne contamination	Passive Engineering Control	Operators are exposed to airborne contamination due to failure of containment hood	Intermediate Chemical	38.25.1.1	B

9.0 DEFINITIONS

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 5-7), or a quantifiable probability of less than an index of -4 exists. For nuclear criticality safety purposes, a system that possesses 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 5-7), or a quantifiable probability of less than 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 unquestionably 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.

Baseline Design Natural Phenomena Event – 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 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.

10.0 REFERENCES

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APPENDIX 1

Appendix 1
Figure A1-1 OCB Dryer System Process Flow Diagram

Appendix 1
Figure A1-2 OCB Calciner System Process Flow Diagram

Appendix 1
Figure A1-3 OCB Dryer/Calciner Offgas System Process Flow Diagram

Appendix 1
Figure A1-4 OCB CP Blender and Download System Process Flow Diagram

Appendix 1
Figure A1-5 OCB Powder Dissolver System Process Flow Diagram

Appendix 1
Figure A1-6 OCB ADU Precipitation System Process Flow Diagram

Appendix 1
Figure A1-7 OCB ADU Slurry Handling System Process Flow Diagram

Appendix 1
Figure A1-8 OCB Crossflow Filtration System Process Flow Diagram

Appendix 1
Figure A1-9 OCB Ion Exchange System Process Flow Diagram

Appendix 1
Figure A1-10 OCB Ion Exchange Eluate System Process Flow Diagram

Appendix 1
Figure A1-11 OCB Miscellaneous Solution Recycle System Process Flow Diagram

Appendix 1

Figure A1-12 EPB Ammonia Recovery System Process Flow Diagram

Appendix 1
Figure A1-13 EPB Liquid Waste System Process Flow Diagram

Appendix 1
Figure A1-14 EPB Boiler System Process Flow Diagram