Enclosure 3

Mark-up Pages
to the

Safety Analysis Report

SAFETY ANALYSIS REPORT

LAR 23-02

Markups for LAR 23-02, Raising Enrichment Limit for LEU+ and Associated Changes

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ACRONYMS AND ABBREVIATIONS

M&TE	measuring and test equipment
MAPEP	Mixed Analyte Performance Evaluation Program
max.	maximum
MC&A	material control and accountability
MCL	maximum contaminant level
MCNP	Monte Carlo N-Particle
MDA	minimum detectable activity
MDC	minimum detectable concentration
ME&I	mechanical, electrical and instrumentation
min.	minimum
MM	modified mercalli
MMI	modified mercalli intensity
MOU	Memorandum of Understanding
MOX	mixed oxide fuel
MUA	multi-attribute utility analysis
N	north
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautic Space Administration
NCA	Noise Control Act
NCRP	National Council on Radiological Protection and Measurements
NCS	nuclear criticality safety
NCSA	nuclear criticality safety analysis
NCSE	nuclear criticality safety evaluation
NDA	Non-destructive assessment
NE	Northeast
NEF	National Enrichment Facility
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act
NELAC	National Environmental Laboratory Accreditation Conference
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NM	New Mexico
NMAC	New Mexico Administrative Code
NMDGF	New Mexico Department of Game and Fish
NMED	New Mexico Environmental Department
NMHWB	New Mexico Hazardous Waste Bureau
NMRPR	New Mexico Radiation Protection Regulations
NMSA	New Mexico State Agency

ACRONYMS AND ABBREVIATIONS

SVOC	semivolatile organic compounds
SW	southwest
SWPPP	Storm Water Pollution Prevention Plan
TDEC	Tennessee Department of Environment and Conservation
TDS	Total Dissolved Solids
TEDE	total effective dose equivalent
TLD	thermoluminescent dosimeter
TN	Tennessee
TSB	Technical Services Building
TSP	total suspended particulates
TVA	Tennessee Valley Authority
TWA	time weighted average
TWDB	Texas Water Development Board
TX	Texas
UBC	Uranium byproduct cylinder
UCL	Urenco Capenhurst Limited
UCN	Ultra-Centrifuge Netherlands NV
UNAMAP	Users Network for Applied Modeling of Air Pollution
UPS	uninterruptible power supply
US	United States
USACE	United States Army Corps of Engineers
USM	Utilities Service Module
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USL	Upper Safety Limit
UV	ultraviolet
VOC	volatile organic compound
W	West
WCS	Waste Control Specialists
WIPP	Waste Isolation Pilot Plant
WMA	wildlife management area
WNA	World Nuclear Association
WNW	west-northwest
WQB	Water Quality Bureau
WQCC	Water Quality Control Commission
WSW	west-southwest

1.1 Facility and Process Description

The NEF, a state-of-the-art process plant, is located in southeastern New Mexico in Lea County approximately 0.8 km (0.5 mi) west of the Texas state border. This location is approximately 8 km (5 mi) due east of Eunice and 32 km (20 mi) south of Hobbs.

The geographic location of the facility is shown on Figures 1.1-1, State Map, and 1.1-2, County Map.

This uranium enrichment plant is based on a highly reliable gas centrifuge process. The process, entirely physical in nature, takes advantage of the tendency of materials of differing density to segregate in the force field produced by a centrifuge. The chemical form of the working material of the plant, uranium hexafluoride (UF_6), does not require chemical transformations at any stage of the process. This process enriches natural UF_6, containing approximately 0.711 $^{w}/_{o}$ ~~wt %~~ ^{235}U or depleted UF_6, containing less than 0.711 $^{w}/_{o}$ ~~wt. %~~ ^{235}U to a UF_6 product, containing ^{235}U enriched up to the LES license limit in isotope ^{235}U.

Feed is received at the plant in specially designed cylinders containing up to 12.7 MT (14 tons) of UF_6. The cylinders are inspected and weighed in the Cylinder Receipt and Dispatch Building (CRDB) or UBC Storage Pad and transferred to the Separations Building Modules (SBMs). SBMs are divided into two Cascade Halls, and each Cascade Hall is comprised of 12 cascades. Each Cascade Hall produces enriched UF_6 at a specified assay ($^{w}/_{o}$ ^{235}U), so two different assays could be produced at one time in an SBM.

The enrichment process, housed in the SBMs, is comprised of four major elements: UF_6 Feed System, Cascade System, Product Take-off System, and Tails Take-off System. Other product related functions include the Product Blending and Liquid Sampling Systems, and Contingency Dump System. Supporting functions include sample analysis, equipment decontamination and rebuild, liquid effluent collection, and solid waste management.

The major equipment used in the UF_6 feed process are Solid Feed Stations. Feed cylinders are loaded into Solid Feed Stations; vented for removal of light gases, primarily air and hydrogen fluoride (HF). The light gases and UF_6 gas generated during venting are routed to the Feed Purification Subsystem where the UF_6 is desublimed. Upon completion of venting, the feed cylinder is heated to sublime the UF_6 for use as feed gas for the centrifuges.

The major pieces of equipment in the Feed Purification Subsystem are UF_6 Cold Traps, a Vacuum Pump/Chemical Trap Sets, and a Low Temperature Take-off Stations (LTTS). The Feed Purification Subsystem removes any light gases such as air, HF, and trace amounts of F_2 from the UF_6 prior to introduction into the cascades. UF_6 is captured in UF_6 Cold Traps and ultimately recycled as feed, while HF is captured on chemical traps.

After purification, UF_6 from the Solid Feed Stations is routed to the Cascade System for production. Pressure in all process lines is subatmospheric. UF_6 feed may also be transferred to empty product~~30B~~ cylinders, bypassing the process system. These ~~30B feed~~product cylinders filled with feed material are strictly for offsite activity.

Gaseous UF_6 from the Solid Feed Stations is routed to the centrifuge cascades. Each centrifuge has a thin-walled, vertical, cylindrically shaped rotor that spins around a central post within an outer casing. Feed, product, and tails streams enter and leave the centrifuge through the central post. Control valves, restrictor orifices, and controllers provide uniform flow of product and tails.

Depleted UF_6 exiting the cascades are transported from the high vacuum of the centrifuge for desublimation into Uranium Byproduct Cylinders (UBCs) at subatmospheric pressure. The primary equipment of the Tails Take-off System is the vacuum pumps and the Tails Low Temperature Take-off Stations (LTTS). Chilled air flows over cylinders in the Tails LTTS to effect the desublimation. Filling of the cylinders is monitored with a load cell system, and filled cylinders are transferred to an outdoor storage area (UBC Storage Pad).

Enriched UF_6 from the cascades is desublimed in a Product Take-off System comprised of vacuum pumps, Product Low Temperature Take-off Stations (LTTS), UF_6 Cold Traps, and Vacuum Pump/Chemical Trap Sets. The pumps transport the UF_6 from the cascades to the Product LTTS at subatmospheric pressure. The heat of desublimation of the UF_6 is removed by cooling air routed through the LTTS. The product stream normally contains small amounts of light gases that may have passed through the centrifuges. Therefore, a UF_6 Cold Trap and Vacuum Pump/Trap Set are provided to vent these gases from the product cylinder. Any UF_6 captured in the cold trap is periodically transferred to another product cylinder for use as product or blending stock. Filling of the product cylinders is monitored with a load cell system, and filled cylinders are transferred to the Product Liquid Sampling System for sampling.

Sampling is performed to verify product assay level ($^{w}/_{o}$ ^{235}U). The Product Liquid Sampling Autoclave is an electrically heated, closed pressure vessel used to liquefy the UF_6 and allow collection of a sample. The autoclave is fitted with a hydraulic tilting mechanism that elevates one end of the autoclave so that liquid UF_6 pours into a sampling manifold connected to the cylinder valve. After sampling, the autoclave is brought back to the horizontal position and the cylinder is indirectly cooled by water flowing through coils located on the outer shell of the autoclave.

LES customers may require product at enrichment levels other than that produced by a single Cascade Hall. Therefore, the plant has the capability to blend enriched UF_6 from two donor cylinders of different assays into a product receiver cylinder. The Product Blending System is comprised of two Blending Donor Stations and two Blending Receiver Stations, where each station can hold one ~~30B~~product cylinder. The Donor Stations are similar to the Solid Feed Stations described earlier. The Receiver Station is similar to the Low-Temperature Take-off Stations described earlier.

Natural UF_6 may be transferred directly from a 48Y cylinder to a ~~30B~~product cylinder, bypassing the cascade system in support of offsite activities. This is accomplished by a connection from a test valve terminal point on the Feed system to a test valve terminal point on the inlet of a Product LTTS. This allows for a 48Y cylinder to transfer from either a Solid Feed Station or a Feed Purification LTTS to the Product LTTS.

Support functions, including sample analysis, equipment decontamination and rebuild, liquid effluent collection, and solid waste management are principally conducted in the Cylinder Receipt and Dispatch Building (CRDB). Decontamination, primarily of pumps and valves, uses solutions of citric acid. Sampling includes a Chemical Laboratory for verifying product UF_6 assay, and an Environmental Monitoring Laboratory (in the TSB). Liquid effluent is collected in the Liquid Effluent Collection and Transfer System (LECTS).

- Filtration and exhaust of gaseous effluent through Gaseous Effluent Vent Systems (GEVS)
- HVAC equipment (supporting radiological and non-radiological portions of the CRDB)

Source material and SNM are used in the CRDB.

Uranium Byproduct Cylinder (UBC) Storage Pad

(See 12.2.1.4) The facility utilizes an area outside of the CRDB, the UBC Storage Pad, for storage of cylinders containing UF_6 that is depleted in ^{235}U. The UBC Storage Pad also provides buffered storage for feed cylinders. The cylinder contents are stored under vacuum in corrosion-resistant ANSI N14.1 Model 48Y cylinders. Additionally, the UBC Storage Pad provides buffered storage for clean, empty ~~Model 30B~~ product cylinders.

The UBC storage area layout is designed for moving the cylinders with a transporter/mover (e.g., a semi-tractor trailer) and a crane. A transporter/mover moves the UBCs between the CRDB to the UBC Storage Pad entrance, and vice versa. A double girder outdoor gantry crane or single girder mobile gantry crane removes the cylinders from the transporter/mover and places them in the UBC Storage Pad. The outdoor gantry crane is designed to triple stack the cylinders in the storage area. The mobile gantry crane is designed to double stack cylinders in the storage area.

Source material is used in this area.

Central Utilities Building

(See 12.2.1.5) The Central Utilities Building (CUB) is shown on Figure 1.1-18, Central Utilities Building First Floor. The Central Utilities Building houses two diesel generators, which provide the site with standby power. The rooms housing the diesel generators are constructed independent of each other with adequate provisions made for maintenance, equipment removal and equipment replacement. The building also contains Electrical Rooms/Areas, an Air Compressor Area, and Centrifuge Cooling Water System.

Utilities Service Module

The Utilities Service Module houses two diesel generators, which provide SBM-1005 with standby power. The rooms housing the diesel generators are constructed independent of each other with adequate provisions made for maintenance, equipment removal and equipment replacement. The building also contains Electrical Rooms/Areas, an Air Compressor Area, and Centrifuge Cooling Water System.

1.1.3 Process Descriptions

This section provides a description of the various processes analyzed as part of the Integrated Safety Analysis. A brief overview of the entire enrichment process is provided followed by an overview of each major process system.

1.1.3.1 Process Overview

The primary function of the facility is to enrich natural or depleted uranium hexafluoride (UF_6) by separating a feed stream of UF_6 into a product stream enriched in ^{235}U and a tails stream depleted in the ^{235}U isotope. The feed material for the enrichment process is UF_6 with a natural composition of isotopes ^{234}U, ^{235}U, and ^{238}U or depleted ^{235}U content (i.e., tails). The enrichment process is a mechanical separation of isotopes using a fast rotating cylinder (centrifuge) based on a difference in centrifugal forces due to differences in molecular weight of the uranic isotopes. No chemical changes or nuclear reactions take place. The feed, product, and tails streams are all in the form of UF_6.

1.1.3.2 Process System Descriptions

An overview of the four enrichment process systems and the two enrichment support systems is discussed below.

Numerous substances associated with the enrichment process could pose hazards if they were released into the environment. Chapter 6, Chemical Process Safety, contains a discussion of the criteria and identification of the chemicals of concern at the NEF and concludes that uranium hexafluoride (UF_6) is the only chemical of concern that will be used at the facility. Chapter 6, Chemical Process Safety, also identifies the locations where UF_6 is stored or used in the facility and includes a detailed discussion and description of the hazardous characteristics of UF_6 as well as a detailed listing of other chemicals that are in use at the facility.

The enrichment process is comprised of the following major systems:

UF_6 Feed System

The first step in the process is the receipt of the feed cylinders and preparation to feed the UF_6 through the enrichment process.

Natural UF_6 feed is received at the NEF in 48Ycylinders from a conversion plant. Pressure in the feed cylinders is below atmospheric (vacuum) and the UF_6 is in solid form.

The function of the UF_6 Feed System is to provide a continuous supply of gaseous UF_6 from the feed cylinders to the cascades.

A Solid Feed Station and Feed Purification Low Temperature Take-off Station have the ability to transfer Natural UF_6 feed from a 48Y cylinder directly to a Product Low Temperature Take-off Station ~~30B~~product cylinder, bypassing the cascade system. This is accomplished through a connection made from test valve terminals on either system.

Cascade System

The function of the Cascade System is to receive gaseous UF_6 from the UF_6 Feed System and enrich the UF_6 up to the LES license limit in isotope ^{235}U.

Multiple gas centrifuges make up arrays called cascades. The cascades separate gaseous UF_6 feed with a uranium isotopic concentration (0.711 $^{w}/_{o}$ ^{235}U or less) into two process flow streams – product and tails. The tails stream is UF_6 that has been depleted of ^{235}U isotope to 0.1 to 0.5 $^{w}/_{o}$ ^{235}U.

Product Take-off System

The function of the Product Take-off System is to provide continuous withdrawal of the enriched gaseous UF_6 product from the cascades and to purge and dispose of light gas impurities from the enrichment process.

The product streams leaving the cascades are brought together into one common manifold from the Cascade Hall. The product stream is transported via a train of vacuum pumps to Product LTTS in the UF_6 Handling Area. There are five Product LTTS per Cascade Hall.

The Product Take-off System also contains a system to purge light gases (typically air and HF) from the enrichment process. This system consists of UF_6 Cold Traps which capture UF_6 while leaving the light gas in a gaseous state. The cold trap is followed by product vent Vacuum Pump/Trap Sets, each consisting of a carbon trap, an alumina trap, and a vacuum pump. The carbon trap removes small traces of UF_6 and the alumina trap removes any HF from the product gas.

Tails Take-off System

The primary function of the Tails Take-off System is to provide continuous withdrawal of the gaseous UF_6 tails from the cascades. A secondary function of this system is to provide a means for removal of UF_6 from the centrifuge cascades under abnormal conditions.

The tails stream exits each Cascade Hall via a primary header, goes through a pumping train, and then to Tails LTTS in the UF_6 Handling Area. There are eight Tails LTTS per Cascade Hall. In addition to the four primary systems listed above, there are two major support systems:

Product Blending System

The primary function of the Product Blending System is to provide a means to fill ~~30B~~product cylinders with UF_6 at a specific enrichment of ^{235}U to meet customer requirements. This is accomplished by blending (mixing) UF_6 at two different enrichment levels to one specific enrichment level. The system can also be used to transfer product from a ~~30B~~product cylinder to another ~~30B~~product cylinder without blending.

The Product Take-off System also provides a method for transferring natural feed from a 48Y cylinder to a ~~30B~~product cylinder to support off-site operations. This is accomplished by a connection from a Feed System test valve terminal point to a test valve terminal point leading to a Product LTTS. This method bypasses the cascade system.

This system consists of Blending Donor Stations (which are similar to the Solid Feed Stations) and Blending Receiver Stations (which are similar to the Product LTTS) described under the primary systems.

Product Liquid Sampling System

The function of the Product Liquid Sampling System is to obtain an assay sample from filled ~~30B~~product cylinders. The sample is used to validate the exact enrichment level of UF_6 in the filled ~~30B~~product cylinders before the cylinders are sent to the fuel processor.

1.1 Facility and Process Description

The Product Liquid Sampling System is one of two systems at NEF that changes solid UF_6 to liquid UF_6. The Sub-Sampling System also changes solid UF_6 to liquid UF_6.

1.1.4 Raw Materials, By-Products, Wastes, And Finished Products

The facility handles Special Nuclear Material of ^{235}U contained in uranium enriched above natural but less than or equal to the LES license limit in ^{235}U isotope. The ^{235}U is in the form of uranium hexafluoride (UF_6). The facility processes approximately 690 feed cylinders (Model 48Y), 350 product cylinders ~~(Model 30B)~~, and 625 UBCs (Model 48Y) per year.

LES does not propose possession of any reflectors or moderators with special characteristics.

Solid Waste Management

(See 12.2.3.3) Solid waste generated at UUSA will be grouped into industrial (non-hazardous), radioactive, hazardous, and mixed waste categories. In addition, solid radioactive and mixed waste is further segregated according to the quantity of liquid that is not readily separable from the solid material. The solid waste management systems are comprised of a set of facilities, administrative procedures, and practices that provide for the collection, temporary storage, processing, and transportation for disposal of categorized solid waste in accordance with regulatory requirements. All solid radioactive wastes generated are Class A low-level wastes (LLW) as defined in 10 CFR 61 (CFR, 2003a).

Radioactive waste is collected in labeled containers in each Radioactive Material Area and transferred to the Solid Waste Collection Room for processing. Suitable waste will be volume-reduced, and all radioactive waste will be disposed of at a licensed LLW disposal facility.

Hazardous waste and a small amount of mixed waste are generated at UUSA. These wastes are also collected at the point of generation and transferred to the Solid Waste Collection Room. Any mixed waste that may be processed to meet land disposal requirements may be treated in its original collection container and shipped as LLW for disposal.

Industrial waste, including miscellaneous trash, filters, resins and paper is shipped offsite for compaction and then sent to a licensed waste landfill.

Effluent Systems

The following UUSA systems handle wastes and effluent.

- Pumped Extract GEVS (PXGEVS)
- Local Extract GEVS (LXGEVS)
- CRDB GEVS
- Liquid Effluent Collection and Transfer System
- Centrifuge Test and Post Mortem Facilities Exhaust Filtration System
- Sewage System
- Solid Waste Collection System
- Decontamination System

3.4 Compliance Item Commitments

3.4.1 Accident Sequences

~~For accident sequences PT3-5, FR1-1, FR1-2, FR2-1, FR2-2, DS1-1, DS1-2, DS2-1, DS2-2, DS3-1, DS3-2, SW1-1, SW1-2, LW1-2, LW1-3, and EC3-1, an Initiating Event Frequency (IEF) index number of "-2" may be assigned based on evidence from the operating history of similar designed URENCO European plants. Detailed justifications for the IEF index numbers of "-2" will be developed during detailed design. If the detailed justification does not support the IEF index number of "-2," then the IEF index number assigned and the associated accident sequence(s) will be re-evaluated and revised, as necessary, consistent with overall ISA methodology~~. Deleted

3.4.2 Administrative Control IROFS that involve "use of" a component or device

For Administrative Control IROFS that involve "use of" a component or device, a Failure Probability Index Number (FPIN) of "-2" may be assigned provided the IROFS is a routine, simple, action that either: (1) involves only one or two decision points or (2) is highly detailed in the associated implementing procedure. Alternately, an FPIN of "-3" may be assigned for this type of IROFS provided the criteria specified above for an FPIN of "-2" are met and the IROFS is enhanced by requiring independent verification of the safety function. This enhancement shall meet the requirements for independent verification identified in item 3.4.5 below. If these criteria cannot be met, then the FPIN assigned to the IROFS and the associated accident sequence(s) will be re-evaluated and revised, as necessary, consistent with the overall ISA methodology.

3.4.3 Administrative Control IROFS that involve "verification of" a state or condition

For Administrative Control IROFS that involve "verification of" a state or condition, an FPIN of "-2" may be assigned provided the IROFS is a routine action performed by one person, with proceduralized, objective, acceptance criteria. Alternately, an FPIN of "-3" may be assigned for this type of IROFS provided the criteria specified above for an FPIN of "-2" are met and the IROFS is enhanced by requiring independent verification of the safety function. This enhancement shall meet the requirements for independent verification identified in item 3.4.5 below. If these criteria cannot be met, then the FPIN assigned to the IROFS and the associated accident sequence(s) will be re-evaluated and revised, as necessary, consistent with the overall ISA methodology.

3.4.4 Administrative Control IROFS that involve "independent sampling"

For Administrative Control IROFS that involve "independent sampling," different samples are obtained and an FPIN of "-2" may be assigned provided at least three of the following four criteria are met.

a. Different methods/techniques are used for sample analysis.

b. Samples are obtained from different locations or (for liquids) sufficiently agitated or mixed by recirculation before withdrawal to ensure results are meaningful and representative of the material sampled.

3.6 Chapter 3 Tables

Table 3.3-1 Cascade System Codes and Standards

The Centrifuge Machine Passive Isolation Devices is designed, constructed, tested, and maintained to QA Level 1.
Rotating equipment is designed in accordance with the appropriate industry codes and standards.
Heat transfer equipment is designed in accordance with the appropriate industry codes and standards.
All miscellaneous equipment is designed in accordance with the appropriate industry codes and standards.
All process piping in the Cascade System shall meet or exceed the requirements of American Society of Mechanical Engineers, Process Piping, ASME B31.3.
The design of electrical systems and components in the Cascade System is in conformance with the requirements of the National Electrical Safety Code, IEEE C2, and New Mexico Electric Code (based on the National Electric Code, NFPA 70), and appropriate industry codes and standards.

Editions of Codes, Standards, NRC Documents, etc are listed in ISAS Table 3.0-1.

Table 3.3-2 Product Take-off System Codes and Standards

The equipment IROFS are designed, constructed, tested, and maintained to QA Level 1.
Rotating equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 rotating equipment in the Product Take-off System.
Heat transfer equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 heat transfer equipment in the Product Take-off System.
Material handling equipment is designed in accordance with the appropriate industry codes and standards and the requirements of the Occupational Safety and Health Administration. There is no QA Level 1 material handling equipment in the Product Take-off System.
All miscellaneous equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 miscellaneous equipment in the Product Take-off System.
All process piping in the Product Take-off System shall meet or exceed the requirements of American Society of Mechanical Engineers, Process Piping, ASME B31.3.
~~All 30-in cylinders used in the Product Take-off System comply with the requirements of ANSI N14.1, Uranium Hexafluoride Packaging for Transport.~~

Editions of Codes, Standards, NRC Documents, etc are listed in ISAS Table 3.0-1.

Table 3.3-3 Tails Take-off System Codes and Standards

The equipment IROFS are designed, constructed, tested, and maintained to QA Level 1.
Rotating equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 rotating equipment in the Tails Take-off System.
Heat transfer equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 heat transfer equipment in the Tails Take-off System.
Material handling equipment is designed in accordance with the appropriate industry codes and standards and the requirements of the Occupational Safety and Health Administration. There is no QA Level 1 material handling equipment in the Tails Take-off System.
All miscellaneous equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 miscellaneous equipment in the Tails Take-off System.
All process piping in the Tails Take-off System shall meet or exceed the requirements of American Society of Mechanical Engineers, Process Piping, ASME B31.3.
All 48-in cylinders used in the Tails Take-off System comply with the requirements of ANSI N14.1, Uranium Hexafluoride Packaging for Transport.

Editions of Codes, Standards, NRC Documents, etc are listed in ISAS Table 3.0-1.

Table 3.3-4 Product Blending System Codes and Standards

The equipment IROFS are designed, constructed, tested, and maintained to QA Level 1.
Rotating equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 rotating equipment in the Product Blending System.
Heat transfer equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 heat transfer equipment in the Product Blending System.
Material handling equipment is designed in accordance with the appropriate industry codes and standards and the requirements of the Occupational Safety and Health Administration. There is no QA Level 1 material handling equipment in the Product Blending System.
All miscellaneous equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 miscellaneous equipment in the Product Blending System.
All process piping in the Product Blending System shall meet or exceed the requirements of American Society of Mechanical Engineers, Process Piping, ASME B31.3.
~~All 30-in cylinders used in the Product Blending System comply with the requirements of ANSI N14.1, Uranium Hexafluoride Packaging for Transport.~~

Editions of Codes, Standards, NRC Documents, etc., are listed in ISAS Table 3.0-1.

Table 3.3-5 Product Liquid Sampling System Codes and Standards

The equipment IROFS are designed, constructed, tested, and maintained to QA Level 1.
Product Liquid Sampling Autoclaves and their supports are designed to meet the requirements of the American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Section VIII, Division I.
Rotating equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 rotating equipment in the Product Liquid Sampling System.
Heat transfer equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 heat transfer equipment in the Product Liquid Sampling System.
Material handling equipment is designed in accordance with the appropriate industry codes and standards and the requirements of the Occupational Safety and Health Administration. There is no QA Level 1 material handling equipment in the Product Liquid Sampling System.
All miscellaneous equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 miscellaneous equipment in the Product Liquid Sampling System.
All process piping in the Product Liquid Sampling System shall meet or exceed the requirements of American Society of Mechanical Engineers, Process Piping, ASME B31.3.
All 1.5-in ~~and 30-in~~ cylinders used in the Product Liquid Sampling System comply with the requirements of ANSI N14.1, Uranium Hexafluoride Packaging for Transport.

Editions of Codes, Standards, NRC Documents, etc are listed in ISAS Table 3.0-1.

Table 3.3-6 Contingency Dump System Codes and Standards

The equipment IROFS are designed, constructed, tested, and maintained to QA Level 1.
Rotating equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 rotating equipment in the Contingency Dump System.
Heat transfer equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 heat transfer equipment in the Contingency Dump System.
All miscellaneous equipment is designed in accordance with the appropriate industry codes and standards. There is no QA Level 1 miscellaneous equipment in the Contingency Dump System.
All process piping in the Contingency Dump System meets or exceeds the requirements of American Society of Mechanical Engineers, Process Piping, ASME B31.3.

Editions of Codes, Standards, NRC Documents, etc are listed in ISAS Table 3.0-1.

Table 3.4-1 Administrative Control IROFS Support Equipment

IROFS	Monitoring Support Equipment	Other Equipment	Equipment Attributes	Operated Support Equipment	Other Equipment	Equipment Attributes
IROFS24c	None	GEVS Alarm (audio/visual) on MFDT Tell-tail	Accurate and reliable indication of operability of CRDB GEVS Accurate and reliable indication of airflow away from worker	None	CRDB GEVS	Provide Airflow / Ventilation away from worker
~~IROFS30a~~	~~None~~	~~None~~	~~None~~	~~None~~	~~None~~	~~None~~
IROFS30b	None	Oil analyzer	Accurate and reliable indication	None	None	None
IROFS30c	None	Oil analyzer	Accurate and reliable indication	None	None	None
IROFS31a	None	Instrument for determining gross ^{235}U content, independent of IROFS31b	Accurate and reliable indication	None	None	None
IROFS31b	None	Instrument for determining gross ^{235}U content, independent of IROFS31a	Accurate and reliable indication	None	None	None
IROFS36a	None	None	None	None	None	None
IROFS36c	None	Fuel Tank	Fuel Tank Volume	None	None	None

Table 3.4-1 Administrative Control IROFS Support Equipment

IROFS	Monitoring Support Equipment	Other Equipment	Equipment Attributes	Operated Support Equipment	Other Equipment	Equipment Attributes
IROFS36d	None	None	None	None	None	None
IROFS36e	None	Fuel Tank	Fuel Tank Volume	None	None	None
IROFS36e IROFS36f	None	UBC Storage Pad Slope	Slope of the Pad to prevent excess pooling	None	None	None
	None	Topographical survey equipment	Accurate and reliable topography reading	None	None	None
IROFS36i	None	None	None	None	None	None
IROFS39a	None	None	None	None	None	None
IROFS39b	None	None	None	None	None	None
IROFS39c	None	None	None	None	None	None
IROFS39d	None	None	None	None	None	None
IROFS42	Weigh Scale System including local digital readout from weighing system at the cylinder stations ***(Notes 2 and 3)**	None	Accurate and reliable indication	None	None	None
IROFS46	None	None	None	None	None	None

Table 3.4-1 Administrative Control IROFS Support Equipment

IROFS	Monitoring Support Equipment	Other Equipment	Equipment Attributes	Operated Support Equipment	Other Equipment	Equipment Attributes
IROFS56b	None	Instrument for determining gross ^{235}U content independent of IROFS56a	Accurate and reliable indication	None	None	None
IROFS57a	None	Instrument for determining gross ^{235}U content independent of IROFS57b	Accurate and reliable indication	None	Circulation pumps (for MFDT baths)	Supports withdrawal of representative sample
IROFS57b	None	Instrument for determining gross ^{235}U content independent of IROFS57a	Accurate and reliable indication	None	Circulation pumps (for MFDT baths)	Supports withdrawal of representative sample
~~IROFS58a~~	~~None~~	~~Instrument for determining gross ^{235}U content~~	~~Accurate and reliable indication~~	~~None~~	~~None~~	~~None~~
~~IROFS58b~~	~~None~~	~~None~~	~~None~~	~~None~~	~~Storage Array~~	~~Provides adequate spacing~~
IROFS60	None	Oxygen Sensor	Accurate and reliable indication of displacement of O_2 by inert gas	None	Glove Bag	Provides enclosure for inert gas
	None	None	None	None	Inert Gas	Provides non-reactive environment

Table 3.4-1 Administrative Control IROFS Support Equipment

IROFS	Monitoring Support Equipment	Other Equipment	Equipment Attributes	Operated Support Equipment	Other Equipment	Equipment Attributes
IROFS61	None	None	None	None	Inert Gas	Provides non-reactive environment
IROFS61	None	None	None	None	Mobile Rigs	Provides method of purge
IROFS101	None	Instrument for determining U mass and enrichment of NaF traps	Accurate and reliable indication	None	None	None
IROFS62	None	None	None	Select independent isolation valves *(Note 2)	Lockout Equipment (includes tags and locks)	Valve position
IROFS63	None	None	None	Select independent isolation valves *(Note 2)	Lockout Equipment (includes tags and locks)	Valve position
IROFS106a	None	Instrument for determining enrichment level of product cylinder	Accurate and reliable indication	None	None	None
IROFS106b	None	Instrument for determining enrichment level of product cylinder	Accurate and reliable indication	None	None	None

Table 3.4-1 Administrative Control IROFS Support Equipment

IROFS	Monitoring Support Equipment	Other Equipment	Equipment Attributes	Operated Support Equipment	Other Equipment	Equipment Attributes
IROFS108a	None	None	None	None	Spacing Device or Mobile Cart with attached Spacing Device	Provides Trap to Trap spacing
IROFS108b	None	None	None	None	Spacing Device or Mobile Cart with attached Spacing Device	Provides Trap to Trap spacing
IROFS110a	None	None	None	None	Mobile Cart with attached Spacing Device	Maintains elevation and spacing of UF_6 process pumps during transport or storage
IROFS110b	None	None	None	None	Mobile Cart with attached Spacing Device	Maintains elevation and spacing of UF_6 process pumps during transport or storage
IROFS111a	None	None	None	None	None	None
IROFS111b	None	None	None	None	None	None

Table 3.4-1 Administrative Control IROFS Support Equipment

IROFS	Monitoring Support Equipment	Other Equipment	Equipment Attributes	Operated Support Equipment	Other Equipment	Equipment Attributes
IROFS118a	None	None	None	None	Stanchions with ropes or retractable belts, or tape on the floor	Visible delineation of array boundary
IROFS118b	None	None	None	None	Stanchions with ropes or retractable belts, or tape on the floor	Visible delineation of array boundary
IROFS120a	None	None	None	None	11 L container Spacing device	Provides volume limited storage Provides adequate spacing between 11L containers in a storage array, and provides adequate spacing between 11L container(s) and transient components
IROFS120b	None	None	None	None	11 L container Spacing device	Provides volume limited storage Provides adequate spacing between 11L containers in a storage array, and provides adequate spacing between 11L container(s) and transient components
IROFS121a	None	None	None	None	None	None

Table 3.4-1 Administrative Control IROFS Support Equipment

IROFS	Monitoring Support Equipment	Other Equipment	Equipment Attributes	Operated Support Equipment	Other Equipment	Equipment Attributes
IROFS121b	None	None	None	None	None	None
IROFS124a	None	None	None	None	None	None
IROFS124b	None	None	None	None	None	None
IROFS165a	None	None	None	None	Tags	Marking of containers/components containing LEU+ material
IROFS165b	None	None	None	None	Tags	Marking of containers/components containing LEU+ material
IROFS166a	N/A	Instrument(s) for determining uranium enrichment level ($^{w}/_{o}$ ^{235}U)	Accurate and reliable indication	None	None	None
IROFS166b	None	None	None	None	None	None
IROFS167a	None	None	None	None	Mobile Cart with attached spacing device, or other spacing device	Provides spacing for a lot of components from edge of cart, or other spacing device
IROFS167b	None	None	None	None	Mobile Cart with attached spacing device, or other spacing device	Provides spacing for a lot of components from edge of cart, or other spacing device

5.1 The Nuclear Criticality Safety (NCS) Program

The facility has been designed and will be constructed and operated such that a nuclear criticality event is prevented, and to meet the regulatory requirements of 10 CFR 70 (CFR, 2003a). Nuclear criticality safety at the facility is assured by designing the facility, systems and components with safety margins such that safe conditions are maintained under normal and abnormal process conditions and any credible accident. Items Relied On For Safety (IROFS) identified to ensure subcriticality are discussed in the UUSA Integrated Safety Analysis Summary.

5.1.1 Management of the Nuclear Criticality Safety (NCS) Program

The NCS criteria in Section 5.2, Methodologies and Technical Practices, are used for managing criticality safety and include adherence to the double contingency principle as stated in the ANSI/ANS-8.1, Nuclear Criticality Safety In Operations with Fissionable Materials Outside Reactors. The adopted double contingency principle states "process design 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." Each process that has accident sequences that could result in an inadvertent nuclear criticality at the UUSA meets the double contingency principle. The UUSA meets the double contingency principle in that process design incorporates sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible.

The plant will produce uranium enriched in isotope ^{235}U no greater than the LES license limit. However, as additional conservatism, most nuclear criticality safety analyses for enriched material are performed assuming a ^{235}U enrichment of 6.0 $^w/_o$ wt% and 11.0 $^w/_o$wt% (for LEU+, except as noted), and include appropriate margins to safety. The exceptions to this are; the systems and components associated with a cascade dump, these include the Contingency Dump System equipment and piping on the 2nd floor of the Process Services Area and the Tails Take-off System, which are analyzed at various bounding enrichment levels for the specific system or component with the systemassuming 1.5 wt% and non-Safe-By-Design tanks which may be limited to 1.0 $^w/_o$ wt% ^{235}U. In accordance with 10 CFR 70.61(d) (CFR, 2003b), the general criticality safety philosophy is to prevent accidental uranium enrichment excesses, provide geometrical safety when practical, provide for moderation controls within the UF_6 processes and impose strict limits on containers of aqueous, solvent based, or acid solutions containing uranium with greater than established threshold values, where the limits are specified in Table 5.1-2. Interaction controls provide for safe movement and storage of components. Plant and equipment features assure prevention of excessive enrichment. The plant is divided into distinctly separate Assay Units (called Cascade Halls) with no common UF_6 piping. UF_6 blending is done in a physically separate portion of the plant. Process piping, individual centrifuges and chemical traps other than the contingency dump chemical traps, are safe by limits placed on their diameters. Product cylinders rely upon uranium enrichment, moderation control and mass limits to protect against the possibility of a criticality event. Each of the liquid effluent collection tanks that hold uranium in solution are controlled via one of the mechanisms specified in Ttable 5.1-2. As required by 10 CFR 70.64(a) (CFR, 2003c), by observing the double contingency principle throughout the plant, a criticality accident is prevented. In addition to the double contingency principle, effective management of the NCS Program includes:

- An NCS program to meet the regulatory requirements of 10 CFR 70 (CFR, 2003a) will be developed, implemented, and maintained.

assumed that UF_6 comes in contact with water to produce aqueous solutions of UO_2F_2 as described in Section 5.2.1.3.3, Uranium Accumulation and Moderation Assumption. A uniform aqueous solution of UO_2F_2, and a fixed enrichment are conservatively modeled using MONK 8A and the JEF2.2 library. Criticality analyses were performed using Monk at 6 $^w/_o$ ~~wt%~~ ^{235}U to determine the maximum value of a parameter to yield $k_{eff} = 1$. The criticality analyses were then repeated to determine the maximum value of the parameter to yield a $k_{eff} = 0.95$.

Similarly, Criticality analyses were performed using MCNP at 11 $^w/_o$ ~~wt%~~ ^{235}U ~~U-235~~ to determine the maximum value of a parameter to yield $k_{eff} = 0.99180$. The criticality analyses were then repeated to determine the maximum value of the parameter to yield a $k_{eff} = 0.958$.

~~-~~Table 5.1-1,~~-~~Safe Values for Uniform Aqueous Solution of Enriched UO_2F_2, shows both the critical and safe limits for 6.0 $^w/_o$ ~~wt%~~ ^{235}U (based on Monk analysis) and at 11.0 $^w/_o$ ~~wt%~~ enrichment (based on MCNP analysis).

Table 5.1-2, Safety Criteria for Buildings/ Systems/Components, lists the safety criteria of Table 5.1-1, Safe Values for Uniform Aqueous Solutions of Enriched UO_2F_2, which are used as control parameters to prevent a nuclear criticality event. Although UUSA is~~will be~~ limited to 5.5 $^w/_o$ ~~wt%~~ enrichment (for non-LEU+ operations), as additional conservatism, the values in the first half of Table 5.1-2, Safety Criteria for Buildings/Systems/ Components, represent the limits based on 6.0 $^w/_o$ ~~wt%~~ enrichment except for the Contingency Dump System equipment and piping on the 2nd floor of the Process Services Corridor~~Area~~ and the Tails Take-off System which are limited to 1.5 $^w/_o$ ~~wt%~~ ^{235}U and non-Safe-By-Design tanks which may be limited to 1.0 $^w/_o$ ~~wt% wt%~~ ^{235}U.

Table 5.1-2 is not applicable to LEU+ systems and components. The nuclear safety of LEU+ systems and components is not based on single item safety criteria, but rather by overall analysis of the configuration.

The values on Table 5.1-1 are chosen to be critically safe when optimum light water moderation exists and reflection is considered within isolated systems. The conservative modeling techniques provide for more conservative values than provided in ANSI/ANS-8.1. The product cylinders are only safe under conditions of limited moderation and enrichment. In such cases, both design and operating procedures are used to assure that these limits are not exceeded.

~~All Separation Plant components, which handle enriched UF_6, other than the Type 30B cylinders and contingency dump chemical traps, are safe by geometry.~~All Separation Plant components which handle enrich UF_6, including product cylinders and contingency dump chemical traps, are criticality safe based on analysis. Centrifuge array criticality is precluded by a probability argument with multiple operational procedure barriers. Total moderator or H/U ratio control as appropriate precludes product cylinder criticality.

In the Cylinder Receipt and Dispatch Building criticality safety for uranium loaded liquids is controlled via one of the mechanisms specified in Table 5.1-2. Individual liquid storage bottles are safe by volume. Interaction in storage arrays is accounted for.

5.1 The Nuclear Criticality Safety (NCS) Program

Based on the criticality analyses, the control parameters applied to UUSA are as follows:

<u>Enrichment</u>

Enrichment is controlled to limit the percent ^{235}U within any process vessel or container to a maximum of the LES license limit except for the systems and components associated with a cascade dump and in certain non-Safe-By-Design tanks noted below. For added conservatism the systems controlled to the LES license limit in isotope ^{235}U are analyzed at 6 ~~-~~$^{w}/_{o}$ ~~wt%~~ and 11 $^{w}/_{o}$~~wt%~~, except as previous noted. The enrichment level may further be restricted in non-Safe-By-Design tanks (e.g., Bulk Storage Tanks, Release Tanks, and Totes) to ≤ 1.0 $^{w}/_{o}$ ~~wt%~~ ^{235}U.

~~Assuming a product enrichment of 6 wt% limits the upper bound for the average cascade enrichment to less than 1.5 wt%, the systems and components associated with a cascade dump (Tails Take-off System, Contingency Sump System) are conservatively analyzed at 1.5 wt%.~~

For added conservatism, for enrichments equal to or greater than 6 $^{w}/_{o}$ ~~wt%~~ specific only to higher enrichment processes, UUSA analyzes at an enrichment value of 1 $^{w}/_{o}$ ~~wt%~~ higher (e.g., LES license limit of 10 $^{w}/_{o}$ ~~wt%~~ - UUSA analyzes at 11 $^{w}/_{o}$~~wt%~~) than the license imit. The exception is for systems where enrichment is the only control used for NCS (e.g., waste storage or off-site shipping from the LECTS[5] – bulk storage tanks, totes, drums, etc.).

<u>Geometry/Volume</u>

Geometry/volume control may be used to ensure criticality safety within specific process operations or vessels, and within storage containers.

The geometry/volume limits are chosen to ensure $k_{eff} = k_{calc} + 3\ \sigma_{calc} < 0.95$ for MONK 8A applications and $k_{eff} = k_{calc} + 2\sigma_{calc} < 0.958$ for MCNP6 applications.

The safe values of geometry/volume in Table 5.1-1 define the characteristic dimension of importance for a single unit such that nuclear criticality safety is not dependent on any other parameter assuming 6 $^{w}/_{o}$ ~~wt%~~ ^{235}U for safety margin for UUSA operations ~~and 11 wt% for LEU+ UUSA operations~~.

<u>Moderation</u>

Water and oil are the moderators considered at UUSA. ~~The only system where moderation is used as a control parameter is in the product cylinders.~~ Moderation control for product cylinders is established consistent with the guidelines of ANSI/ANS-8.22 and incorporates the criteria below:

- Controls are established to limit the amount of moderation entering the cylinders.
- When moderation is the only parameter used for criticality control, the following additional criteria are applied. These controls assure that at least two independent controls would have to fail before a criticality accident is possible.
- Two independent controls are utilized to verify cylinder moderator content.

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[5] Other conservatisms (e.g., moderation, reflection, material) apply to LECTS.

If a unit is considering interaction, nuclear criticality safety analyses are performed. Individual unit multiplication and array interaction are evaluated using Monte Carlo computer code MONK8A to ensure k_{eff}~~k_{eff}~~ = $k_{calc} + 3\ \sigma_{calc} < 0.95$, or MCNP6 to ensure $k_{eff} = k_{calc} + 2\ \sigma_{calc} < 0.958$.

<u>Neutron Absorbers</u>

Neutron Absorption is a factor in almost all of the materials at UUSA. The normal absorption of neutrons in standard materials used in the construction and processes (uranium, fluorine, water, steel, etc.) is not specifically excluded as a criticality control parameter.

Models incorporate conservative values (e.g., material compositions and equipment dimensions), which are validated at receipt, after installation or during surveillances.

Additional materials such as cadmium and boron for which the sole purpose would be to absorb neutrons are not incorporated in UUSA processes. Solutions of absorbers are not used as a criticality control mechanism.

<u>Piece Count</u>

Piece count, which refers to the number of uranic bearing components being modeled may be used as a control. When used as a control, the safe number of components can be established, for example, by dividing the safe mass of a single parameter or safe volume by the component's uranic mass or volume the safe mass of a single parameter or safe volume, respectively.

<u>Concentration and Density</u>

UUSA does not use either concentration or density as a criticality control parameter.

5.1.3 Safe Margins against Criticality

Process operations require establishment of criticality safety limits. The facility UF_6 systems involve mostly gaseous operations. These operations are carried out under reduced atmospheric conditions (vacuum) or at slightly elevated pressures not exceeding three atmospheres. It is highly unlikely that any size changes of process piping, cylinders, cold traps, or chemical traps under these conditions, would lead to a criticality situation because a volume or mass limit may be exceeded.

Within the Separations Building Modules, significant accumulations of enriched UF_6 reside only in the product cylinders and cold traps. The facility design minimizes the possibility of accidental moderation by eliminating water for automatic fire suppression. In addition, the facility's design assures that product cylinders and cold traps do not become unacceptably hydrogen moderated while in process. The plant's UF_6 systems operating procedures contain safeguards against loss of moderation control (ANSI/ANS 8.22).

5.1.4 Description of Safety Criteria

Each portion of the plant, system, or component that may possibly contain enriched uranium is designed with criticality safety as an objective. Table 5.1-2, Safety Criteria for Buildings/ Systems/Components, shows how the safety criteria of Table 5.1-1, Safe Values for Uniform Aqueous Solutions of Enriched UO_2F_2, are applied to the facility to prevent a nuclear criticality event. Although UUSA will be limited to Material License Condition 6B for $^{w}/_{o}$ ~~wt%~~ enrichment, as additional conservatism, the values in Table 5.1-2, represent the limits based on 6.0 $^{w}/_{o}$ ~~wt%~~

enrichment with the previously noted exceptionswith the exception of; the Tails Take-off and Contingency Dump Systems, which are limited to the maximum process system average enrichment, 1.5 wt% and non-Safe-By-Design tanks which may be limited to 1 wt%.

Where there are significant in-process accumulations of enriched uranium as UF_6, the plant design includes multiple features to minimize the possibilities for breakdown of the moderation control limits. These features eliminate direct ingress of water to product cylinders while in process.

5.1.5 Organization and Administration

The criticality safety organization is responsible for implementing the Nuclear Criticality Safety Program.

The Engineering and Projects Manager is accountable for overall criticality safety of the facility, is administratively independent of production responsibilities, and has the authority to shut down potentially unsafe operations.

Designated responsibilities of the Criticality Safety Organization include the following:

- Establish the Nuclear Criticality Safety Program, including design criteria, procedures, and training
- Assess normal and credible abnormal conditions
- Determine criticality safety limits for controlled parameters, with input from the Criticality Safety Engineers
- Develop and validate methods to support nuclear criticality safety evaluations (NCSEs) (i.e., non-calculation engineering judgments regarding whether existing criticality safety analyses bound the issue being evaluated or whether new or revised safety analyses are required)
- Specify criticality safety control requirements and functionality
- Provide advice and counsel on criticality safety control measures
- Support emergency response planning and events
- Evaluate the effectiveness of the Nuclear Criticality Safety Program using audits and assessments
- Provide criticality safety postings that identify administrative controls for operators in applicable work areas.

Criticality Safety Engineers will be provided in sufficient number to support the program technically. They are responsible for the following:

- Provide criticality safety support for integrated safety analyses and configuration control
- Perform NCS analyses (i.e., calculations), write NCS evaluations, and approve proposed changes in process conditions on equipment involving fissionable material

Qualified Criticality Safety Engineers may also perform tasks associated with Criticality Safety program implementation and assessment.

The minimum qualifications for the Criticality Safety Engineer are described in Section 2.2.3. The Criticality Safety Engineer training program is based on ANSI/ANS-8.26, Criticality Safety Engineer Training and Qualification Program. The Engineering and Projects Manager has the authority and responsibility to assign and direct activities for the Criticality Safety Program. The Engineering and Projects Manager is responsible for implementation of the NCS program.

Δ_{SM} is taken as 0.03 per justification provided in the UUSA MCNP6 Validation report (Sanders Engineering, 2022). Δ_{AOA} is set to zero, as the benchmark experiments encompass the range of actual applications at UUSA with the exception of the enrichment variable. The enrichment of the current Contingency Dump System in the previous NCSA is 1.5 $^{w}/_{o}$ ~~wt%~~ ^{235}U (remains bounding of 1.6 $^{w}/_{o}$ value used in LEU+), while the lowest enrichment used in the benchmark calculations is 2 $^{w}/_{o}$~~wt%~~. For enrichments between 0 and 2 $^{w}/_{o}$~~wt%~~ ^{235}U ~~U-235~~, NUREG/CR-6698 Table 2.3 provides an allowable experimental range of ± 1.5 $^{w}/_{o}$~~wt%~~ for the areas of applicability (NRC, 2001). The highest enrichment used in the benchmark calculations is 47 $^{w}/_{o}$~~wt%~~ while future UUSA application may require enrichments up to 50 $^{w}/_{o}$~~wt%~~. NUREG/CR-6698, Table 2.3 allows for a ±15 $^{w}/_{o}$~~wt%~~ extension for benchmarks with enrichments between 20-80 $^{w}/_{o}$~~wt%~~ ^{235}U ~~U-235~~ (NRC, 2001). Accordingly, Δ_{AOA} with respect to an enrichment range of 0.5-50 $^{w}/_{o}$~~wt%~~ ^{235}U ~~U-235~~ is taken as 0.0.

The USL becomes:

USL = 0.98894 – 0.03 – 0.0 = 0.958 (for enrichments of 0.5 to ≤ 50 $^{w}/_{o}$~~wt%~~ ^{235}U ~~U-235~~)

NUREG/CR-6698 indicates that the following condition be demonstrated for all normal and credible abnormal operating conditions (NRC, 2001):

$$k_{calc} + 2\,\sigma_{calc} < USL$$

For the systems or components with enrichments of 0.5 up to ≤ 50 $^{w}/_{o}$~~wt%~~, the nuclear criticality safety criterion for MCNP6 is given by:

$$k_{eff} = k_{calc} + 2\sigma_{calc} < 0.958$$

5.2.1.3 General Nuclear Criticality Safety Methodology

The NCS analyses results provide values of k-effective (k_{eff}) to conservatively meet the upper safety limit. The following sections provide a description of the major assumptions used in the NCS analyses.

5.2.1.3.1 Reflection Assumption

The layout of the NEF is a very open design and it is not considered credible that those vessels and plant components requiring criticality control could become flooded from a source of water within the plant. Full water reflection of vessels has therefore been discounted. However, where appropriate, spurious reflection due to walls, fixtures, personnel, etc. has been accounted for by assuming 2.5 cm (0.984 in) of water reflection around vessels.

5.2.1.3.2 Enrichment Assumption

Enrichment is controlled to limit the percent ^{235}U within any process vessel or container to the LES license limit. For added conservatism most systems controlled to the LES license limit in isotope ^{235}U are analyzed at 6 $^{w}/_{o}$~~wt%~~ and 11 $^{w}/_{o}$~~wt%~~ (for LEU+), except as previously noted. ~~The exceptions to this are; the systems and components associated with a cascade dump,~~

these include the Contingency Dump System equipment and piping on the 2nd floor of the Process Services Area and the Tails Take-off System, which are analyzed assuming 1.5 wt% and non-Safe-By-Design tanks which may be limited to 1.0 w/o ^{235}U.

5.2.1.3.3 Uranium Accumulation and Moderation Assumption

Most components that form part of the centrifuge plant or are connected to it assume that any accumulation of uranium is taken to be in the form of a uranyl fluoride/water mixture at a maximum H/U atomic ratio of 7 (exceptions are discussed in the associated nuclear criticality safety analyses documentation). The ratio is based on the assumption that significant quantities of moderated uranium could only accumulate by reaction between UF_6 and moisture in air leaking into the plant. Due to the high vacuum requirements of a centrifuge plant, in-leakage is controlled at very low levels and thus the H/U ratio of 7 represents an abnormal condition. The maximum H/U ratio of 7 for the uranyl fluoride-water mixture is derived as follows:
The stoichiometric reaction between UF_6 and water vapor in the presence of excess UF_6 can be represented by the equation:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF$$

Due to its hygroscopic nature, the resulting uranyl fluoride is likely to form a hydrate compound. Experimental studies (Lychev, 1990) suggest that solid hydrates of compositions $UO_2F_2 \cdot 1.5H_2O$ and $UO_2F_2 \cdot 2H_2O$ can form in the presence of water vapor, the former composition being the stable form on exposure to atmosphere.

It is assumed that the hydrate $UO_2F_2 \cdot 1.5H_2O$ is formed and, additionally, that the HF produced by the UF_6/water vapor reaction is also retained in the uranic breakdown to give an overall reaction represented by:

$$UF_6 + 3.5H_2O \rightarrow UO_2F_2 \cdot 4HF \cdot 1.5H_2O$$

For the criticality safety calculations, the composition of the breakdown product was simplified to $UO_2F_2 \cdot 3.5H_2O$ that gives the same H/U ratio of 7 as above.

In the case of oils, UF_6 pumps and vacuum pumps use a fully fluorinated perfluorinated polyether (PFPE) type lubricant. Mixtures of UF_6 and PFPE oil would be a less conservative case than a uranyl fluoride/water mixture, since the maximum HF solubility in PFPE is only about 0.1 w/o. Therefore, the uranyl fluoride/water mixture assumption provides additional conservatism in this case.

5.2.1.3.4 Vessel Movement Assumption

The limits placed on movement of an individual vessel or a specified batch of vessels containing enriched uranium are specified in the facility procedures or work plans, both of which are reviewed by Nuclear Criticality Safety. Specified limits may not be required based on bounding or process/system-specific NCS evaluations or analysis.

Of the subset of individual vessels or groups of vessels that do not have specified controls but are bounded by a the single-parameter SBD limits in Table 5.1-1, separation must be maintained at least 60 cm (23.6 in) from any other enriched uranium.

Vessels or groups of vessels that do not comply with either of the statements above must not be moved without the written approval of the Criticality Safety Organization.

5.6 Chapter 5 Tables

Table 5.1-1 Critical and Safe Values for Uniform Aqueous Solutions of Enriched UO_2F_2 at 6.0 $^w/_o$ and 11.0 $^w/_o$

Parameter	Critical Value k_{eff} = 1.0	Safe Value k_{eff} = 0.95	Safety Factor
Values for 6.0 $^w/_o$ enrichment			
Parameter	**Critical Value k_{eff} = 1.0**	**Safe Value k_{eff} = 0.95**	**Safety Factor**
Volume	25.3 L (6.7 gal)	19.3 L (5.1 gal)	0.76
Cylinder Diameter	24.8 cm (9.8 in)	22.4 cm (8.8 in)	0.90
Slab Thickness	11.6 cm (4.6 in)	10.1 cm (4.0 in)	0.87
Water Mass	15.4 kg H_2O (34.0 lb H_2O)	11.9 kg H_2O (26.2 lb H_2O)	0.77
Areal Density	9.4 g U/cm^2 (19.3 lb U/ft^2)	7.9 g U/cm^2 (16.2 lb U/ft^2)	0.84
Uranium Mass	27 kg U (59.5 lb U)		
- no double batching		20.1 kg U (29.7 kg UF_6)	0.74
- no double batching		20.1 kg U (29.7 kg UF_6)	0.74
- double batching		12.2 kg U (26.9 lb U)	0.45
Values for 11.0 $^w/_o$ enrichment			
Parameter	**Critical Value k_{eff} = 0.99339**	**Safe Value k_{eff} = 0.958**	**Safety Factor**
Volume	15.3 L (4.0 gal)	12.8 L (3.3 gal)	0.84
Cylinder Diameter	20.50 cm (8.0 in)	19.10 cm (7.5 in)	0.93
Slab Thickness	8.85 cm (3.4 in)	8.0 cm (3.1 in)	0.9
Areal Density	4.50 g U/cm^2 (9.2 lb U/ft^2)	4.00 g U/cm^2 (8.1 lb U/ft^2)	0.89
Uranium Mass	10.8 kg U (23.8 lb U)		
- no double batching		8.8 kg U (13.0 kg UF_6	0.81
- double batching		4.86 kg U (7.19 lb U)	0.45

5.6 Chapter 5 Tables

Table 5.1-2 Safety Criteria for Buildings/Systems/Components

Values for 6.0 $^{w}/_{o}$ enrichment		
Building/System/Component	**Control Mechanism**	**Safety Criteria**
Enrichment	Enrichment	5.5 $^{w}/_{o}$ (6 $^{w}/_{o}$ ^{235}U used in NCS)
Product Cylinders ~~(30B)~~	Moderation	H < 0.98 kg (2.16 lb)
UF_6 Piping	Diameter	< 22.4 cm (8.8 in)
Chemical Traps	Diameter	< 22.4 cm (8.8 in)
Product Cold Trap	Diameter	< 22.4 cm (8.8 in)
Contingency Dump System Tails System	Enrichment	1.5 $^{w}/_{o}$ ^{235}U (used in NCS)
Tanks (controlled by any one mechanism listed on the right)	Diameter	< 22.4 cm (8.8 in)
	Enrichment	≤ 1.0 $^{w}/_{o}$ ^{235}U (used in NCS for non-Safe-By-Design tanks)
	Mass	< 0.73 kg ^{235}U
	Slab Thickness	< 10.1 cm (4.0 in)
	Volume	< 19.3 L (5.1 gal)
Feed Cylinders	Enrichment	< 0.72 $^{w}/_{o}$ ^{235}U
Uranium Byproduct Cylinders	Enrichment	< 0.72 $^{w}/_{o}$ ^{235}U
UF_6 Pumps	Volume	< 19.3 L (5.1 gal)
Individual Uranic Liquid Containers, e.g., PFPE Oil Bottle, Laboratory Flask, Mop Bucket	Volume	< 19.3 L (5.1 gal)
Vacuum Cleaners Oil Containers	Volume	< 19.3 L (5.1 gal)

Chemisorption is used in the removal of UF_6, HF and trace amounts of F_2 from gaseous effluent streams. It is also used to remove oil mist from vacuum pumps operating upstream of gaseous effluent vent systems. Adsorbent materials are placed on stationary beds in chemical traps downstream of the various cold traps. These materials capture HF and the trace amounts of UF_6 that escape desublimation during feed purification or during venting of residual UF_6 contained in hoses and/or piping that is bled down before disconnection.

The chemical traps are placed in series downstream of the cold traps in the exhaust streams to the GEVS and may include one or more of a series of three different types of chemical traps; sodium fluoride (NaF) traps aluminum oxide (Al_2O_3) traps, and mixed-bed traps, which contain NaF and AL_2O_3 ~~Al2O3~~ in the same housing. The NaF captures HF and small amounts of UF_6 that escape desublimation. F_2 passes through NaF. This necessitates a second type of trap containing a charge of Al_2O_3 to F_2 and any remaining UF_6 or HF from the gaseous effluent stream at normal system operating pressure. One or more of a series of these traps is used depending on the process system being served. ~~Additionally, an oil trap (also containing Al_2O_3) is present on the inlet of the vacuum pumps to prevent pump oil from migrating back into the UF_6 cold traps.~~

NaF is used to trap UF_6 because the chemisorption on NaF is significantly lower than the heat of UF_6 chemisorption on other trap type media. Failures associated with the NaF traps were evaluated in the Integrated Safety Analysis.

There are no specific concerns with heat of adsorption of UF_6, F_2, or HF with Al_2O_3. Although the heat of absorption of HF on NaF and F_2 on Al_2O_3 are relatively large, the quantity of HF or F_2 present at a pump/trap set is relatively small. Failures associated with the sodium fluoride and aluminum oxide traps were evaluated in the Integrated Safety Analysis.

The properties of these chemical adsorbents are provided in Table 6.2-1, Properties of Chemical Adsorbents.

6.2.1.2.3 Decontamination – Citric Acid

Contaminated components (e.g., pumps, valves, piping), once they are removed from the process areas, undergo decontamination. Oily parts are washed in a hot water wash that will remove the bulk of oil including residual uranic compounds. Once the hot water wash is complete, citric acid is used to remove residual uranic fluoride compound layers that are present on the component surfaces. The reaction of the uranium compounds with the citric acid solution produces various uranyl citrate complexes. After citric acid cleansing, the decontaminated component is subject to two additional water wash/rinse cycles. The entire decontamination operation is conducted in small batches on individual components.

Decontamination of sample bottles and valves is also accomplished using citric acid.

Decontamination was evaluated in the Integrated Safety Analysis. Adequate personnel protective features are in place for safely handling decontamination chemicals and byproducts.

6.2.1.2.4 Nitrogen

Gaseous nitrogen is used in the UF_6 systems for purging and filling lines that have been exposed to atmosphere for any of several reasons including: connection and disconnection of

6.2.1.3 UF_6 and Construction Materials

The corrosion of metallic plant components and the deterioration of non-metallic sealing materials are avoided by specifying resistant materials of construction and by controlling process fluid purity.

Direct chemical attack by the process fluid on metallic components is the result of chemical reactions. In many cases, the affinity of the process fluid for the metal produces metallic compounds, suggesting that rapid destruction of the metal would take place. This is usually prevented by the formation of a protective layer on the surface of the metal.

Deterioration of non-metallic materials is caused by exposure to process fluids and conditions. Materials used in gaskets, valves, flexible hoses, and other sealants must be sufficiently inert to have a useful service life.

UF_6 and some of its reaction products are potentially corrosive substances, particularly HF. UF_6 is a fluorinating agent that reacts with most metals. The reaction between UF_6 and metals such as nickel, copper, and aluminum produces a protective fluoride film over the metal that inhibits further reaction. These materials are therefore relatively inert to UF_6 corrosion after passivation and are suitable for UF_6 service. Aluminum is used as piping material for UF_6 systems because it is especially resistant to corrosion in the presence of UF_6. Carbon steels and stainless steels can be attacked by UF_6 at elevated temperatures but are not significantly affected by the presence of UF_6 at the operating temperatures for the facility.

Light gas impurities such as HF and air are removed from UF_6 during the purification process. Although HF is a highly corrosive substance when in solution with water as aqueous hydrofluoric acid, it contributes very little to metal corrosion when in the presence of UF_6. This is due to the fact that UF_6 reacts with water so rapidly that HF remains anhydrous when in the presence of UF_6.

Corrosion rates of certain metals in contact with UF_6 are presented in Table 6.2-2, UF_6 Corrosion Rates, for two different temperatures. Resistant metal such as stainless steel are used in valve bellows and flex hoses. Aluminum piping is bent to minimize the use of fittings. Connections are welded to minimize the use of flanges and gaskets. As a standard practice, the use of sealant materials is minimized to reduce the number of potential leak paths.

Non-metallic materials are required to seal connections in UF_6 systems to facilitate valve and instrument replacement as well as cylinder connections. They are also used in valve packing and seating applications. All gasketing and packing material used at the facility will be confirmed as appropriate for UF_6 services. Typical materials that are resistant to UF_6 through the range of plant operating conditions include butyl rubber, Viton, and Kel-F.

The materials used to contain UF_6 are provided in Table 6.2-3, Materials of Construction for UF_6 Systems. ~~The cylinders to be used at the facility are standard Department of Transportation approved containers for the transport and storage of UF_6, designed and fabricated in accordance with ANSI N14.1.~~ The nominal and minimum (for continued service) wall thickness for cylinders listed in Table 6.2-3, are taken from ~~this~~the ANSI N14.1 standard.

- Tails Take-Off System
- Product Blending System
- Product Liquid Sampling System.

UF_6 is delivered to the plant in ANSI N14.1 standard Type 48Y international transit cylinders, which are placed in a feed station and connected to the plant via a common manifold. Heated air is circulated around the cylinder to sublime UF_6 gas from the solid phase. The gas is flow controlled through a pressure control system for distribution to the cascade system at subatmospheric pressure.

Individual centrifuges are not able to produce the desired product and tails concentration in a single step. They are therefore grouped together in series and in parallel to form arrays known as cascades. A typical cascade is comprised of many centrifuges.

UF_6 is drawn through cascades with vacuum pumps and compressed to a higher subatmospheric pressure at which it can desublime in the receiving cylinders. Highly reliable UF_6 resistant pumps will be used for transferring the process gas.

Tails material and product material are desublimed at separate chilled take-off stations. Tails material is desublimed into 48Y cylinders. Product material is desublimed into ~~30B~~product cylinders.

With the exception of liquid sampling operations, the entire enrichment process operates at subatmospheric pressure. This safety feature helps ensure that releases of UF_6 or HF are minimized because leakage would typically be inward to the system. During sampling operations, UF_6 is liquefied within an autoclave which provides the heating required to homogenize the material for sampling. The autoclave is a rated pressure vessel which serves as secondary containment for the UF_6 ~~30B~~product cylinders while the UF_6 is in a liquid state.

There are numerous subsystems associated with each of the major enrichment process systems as well as other facility support and utility systems. These include systems supporting venting, cooling, electrical power, air and water supply, instrumentation and control and handling functions among others.

6.2.3 Process System Descriptions

Detailed system descriptions and design information for enrichment process and process support systems are provided in the NEF Integrated Safety Analysis Summary. These descriptions include information on process technology including materials of construction, process parameters (e.g., flow, temperature, pressure, etc.), key instrumentation and control including alarms/interlocks, and items relied on for safety (IROFS).

6.2.4 Utility and Support System Descriptions

The UF_6 Enrichment Systems also interface with a number of supporting utility systems. Detailed system descriptions and design information for these utility and support systems are provided in the NEF Integrated Safety Analysis Summary. These descriptions include information on process technology including materials of construction; process parameters (e.g., flow, temperature, pressure, etc.), key instrumentation and control including alarms/interlocks, and (IROFS).

Table 6.1-2 Separations Building Modules

Chemical/Product			Inventory by Location				
Name	Formula	Physical State	UBC Storage Pad (outdoor)[6,7]	UF_6 Handling Area (Typical SBM)[8]	Cascade Halls	Second Floor Process Services Area[9]	Blending and Liquid Sampling Area[10]
Uranium hexafluoride	UF_6	Solid	1.97 E8 kg (4.34 E8 lb)	4.73 E5 kg (1.04 E6 lb)			9,108 kg (20,079 lb)
Uranium hexafluoride	UF_6	Liquid					2,277 kg (5,020 lb) Per autoclave
Uranium hexafluoride	UF_6	Gas		piping	SBM-1001 140 kg/hall SBM-1003 110 kg/hall SBM-1005 110kg kg/hall	SBM-1001 13.8 kg/hall SBM-1003 20kg kg/hall SBM-1005 20kg kg/hall	3 kg (6.6 lb)
Hydrogen fluoride	HF	gas		Piping (trace)			

[6] The UBC Storage Pad is located outside of and detached from the Separations Building.
[7] Not to exceed Material License Condition 8.A for natural and depleted uranium.
[8] For one assay in the UF_6 Handling Area the maximum estimated operational inventory is based on 5 feed (48Y). 2 feed purification (48Y). 11 tails (48Y), and 5 product ~~(30B)~~ cylinders. Future SBMs may contained more feed/tails/product stations. Solid UF_6 can be determined by adding the maximum fill weight for each addition type of cylinder.
[9] Normal estimated operational inventory in piping. Gas flows in piping routed from the UF_6 Handling Area to the Cascades Halls and back. The Process Services Area contains the manifolds and valve stations.
[10] The Blending and Liquid Sampling Area can have up to 2 product~~(30B)~~ cylinders in donor stations and 2 product~~(30B)~~ cylinders in receiver stations. One product~~(30B)~~ cylinder be present in each liquid sampling autoclave and will be in various physical states depending on sampling in progress.

6.6 Chapter 6 Tables

Table 6.2-2 UF_6 Corrosion Rates

Material	Corrosion Rate @ 20°C (68°F) per year	Corrosion Rate @ 100°C (212°F) per year
Aluminum	6.6E-7 mm (2.6E-5 mils)	8.4E-5 mm (3.3E-3 mils)
Stainless Steel	1.4E-4 mm (5.5E-3 mils)	0.03 mm (1.2 mils)
Copper	1.2E-4 mm (4.7E-3 mils)	3.3E-3 mm (1.3E-1 mils)
Nickel	< 0.05 mm (< 2.0 mils)	< 0.05 mm (< 2.0 mils)

Table 6.2-3 Materials of Construction for UF_6 Systems

Component	Material	Wall Thickness (nominal)	Wall Thickness (minimum)
UF_6 Feed Cylinders (48Y) and UBCs (48Y)	Carbon Steel ASTM A516	16 mm (0.625 inch)	12.7 mm (0.5 inch)
UF_6 Product Cylinder (30B)	Carbon Steel ASTM A516	12.7 mm (0.5 inch)	8 mm (0.3125 inch)
UF_6 Product Cylinder (30B-10)	Carbon Steel ASTM A516	13 mm (0.51 inch)	11 mm (0.43 inch)
Sample Bottle (1S)	Nickel/Monel ASTM B162	1.6 mm (0.0625 inch)	1.6 mm (0.0625 inch)
Sample Bottle (2S)	Nickel/Monel ASTM B162	2.8 mm (0.112 inch)	1.6 mm (0.0625 inch)
Sample Bottle (ETC Designed)	Stainless Steel 316L	2.77 mm (0.1091 inch)	n/a
UF_6 Piping	Aluminum & Stainless Steel	3.7 mm (0.147 inch)	Determined During Final Design
UF_6 Valves	Aluminum & Stainless Steel	> 3.7 mm (> 0.147 inch)	Determined During Final Design
Cold Trap	Stainless Steel	8 mm (0.315 inch)	not applicable