

NEF Safety Analysis Report-1.1.3 Process Descriptions

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. Additional details are provided in Chapter 3, Integrated Safety Analysis Summary.

1.1.3.1 Process Overview

The enrichment process at the NEF is basically the same process described in the SAR for the Claiborne Enrichment Center (LES, 1991). The Nuclear Regulatory Commission (NRC) staff documented its review of the Claiborne Enrichment Center license application and concluded that LES's application provided an adequate basis for safety review of facility operations and that construction and operation of the Claiborne Enrichment Center would not pose an undue risk to public health and safety (NRC, 1993). The design of the NEF incorporates the latest safety improvements and design enhancements from the Urenco enrichment facilities currently operating in Europe.

The primary function of the facility is to enrich natural uranium hexafluoride (UF_6) by separating a feed stream containing the naturally occurring proportions of uranium isotopes 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 uranium hexafluoride (UF_6) with a natural composition of isotopes ^{234}U , ^{235}U , and ^{238}U . 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 UF₆.

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 (UF₆) is the only chemical of concern that will be used at the facility. Chapter 6, Chemical Process Safety, also identifies the locations where UF₆ is stored or used in the facility and includes a detailed discussion and description of the hazardous characteristics of UF₆ as well as a detailed listing of other chemicals that are in use at the facility. Additional details on each of the enrichment process systems are provided in Chapter 3, Integrated Safety Analysis Summary. The enrichment process is comprised of the following major systems:

UF₆ Feed System

The first step in the process is the receipt of the feed cylinders and preparation to feed the UF₆ through the enrichment process. Natural UF₆ feed is received at the NEF in 48Y or 48X cylinders from a conversion plant.

Pressure in the feed cylinders is below atmospheric (vacuum) and the UF₆ is in solid form. The function of the UF₆ Feed System is to provide a continuous supply of gaseous UF₆ from the feed cylinders to the cascades. There are six Solid Feed Stations per Cascade Hall; three stations in operation and three on standby. The maximum feed flow rate is 187 kg/hr (412 lb/hr) UF₆ based on a maximum capacity of 545,000 SWU per year per Cascade Hall.

Cascade System

The function of the Cascade System is to receive gaseous UF₆ from the UF₆ Feed

System and enrich the ^{235}U isotope in the UF_6 to a maximum of 5 w/o. Multiple gas centrifuges make up arrays called cascades. The cascades separate gaseous UF_6 feed with a natural uranium isotopic concentration into two process flow streams – product and tails. The product stream is the enriched UF_6 stream, from 2 – 5 w/o ^{235}U , with an average of 4.5 w/o ^{235}U . The tails stream is UF_6 that has been depleted of ^{235}U isotope to 0.20 – 0.34 w/o ^{235}U , with an average of 0.32 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 eight 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; two stations in operation and three stations on standby.

The Product Take-off System also contains a system to purge light gases (typically air and hydrogen fluoride) 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 hydrogen fluoride (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 UF₆ Handling Area. There are ten Tails LTTS per Cascade Hall. Under normal operation, seven of the stations are in operation receiving tails and three are on standby. 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 cylinders with UF₆ at a specific enrichment of ²³⁵U to meet customer requirements. This is accomplished by blending (mixing) UF₆ at two different enrichment levels to one specific enrichment level.

The system can also be used to transfer product from a 30B or 48Y cylinder to another 30B cylinder without blending. 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 product 30B cylinders. The sample is used to validate the exact enrichment level of UF₆ in the filled product cylinders before the cylinders are sent to the fuel processor. This is the only system in the NEF that changes solid UF₆ to liquid UF₆.

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1.1.2 Facilities Description

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The major structures and areas of the facility are outlined below.

Separations Building Modules The overall layout of a Separations Building Module is presented in Figures 1.1-5 through 1.1-7 and the UF₆ Handling Area is shown in Figure 1.1-8, UF₆ Handling Area Equipment Location.

The facility includes three identical Separations Building Modules. Each module consists of two Cascade Halls, each having eight cascades with each cascade having hundreds of centrifuges. Each Cascade Hall is capable of producing approximately 500,000 SWU per year. The major functional areas of the Separations Building Modules are:

- Cascade Halls (2)
- Process Services Area
- UF₆ Handling Area

Source material and special nuclear material (SNM) are used or produced in this area. Additional details of the Separations Building Modules are provided in Chapter 3, Integrated Safety Analysis Summary.

Technical Services Building The overall layout of the Technical Services Building (TSB) is presented in Figures 1.1-9, Technical Services Building First Floor, and 1.1-10, Technical Services Building Second Floor. The TSB contains support areas for the facility. It also acts as the secure point of entry to the Separations Building Modules and the Cylinder Receipt and Dispatch Building (CRDB). The major functional areas of the TSB are:

- Solid Waste Collection Room
- Vacuum Pump Rebuild Workshop
- Decontamination Workshop
- Ventilated Room
- Cylinder Preparation Room
- Mechanical, Electrical and Instrumentation (ME&I) Workshop

- Liquid Effluent Collection and Treatment Room
- Laundry
- TSB Gaseous Effluent Vent System (GEVS) Room
- Mass Spectrometry Laboratory
- Chemical Laboratory
- Environmental Monitoring Laboratory
- Truck Bay/Shipping and Receiving Area
- Medical Room
- Radiation Monitoring Control Room
- Break Room
- Control Room
- Training Room
- Security Alarm Center

Source material and SNM are found in this area. Additional details of the TSB are provided in Chapter 3, Integrated Safety Analysis Summary. Centrifuge Assembly Building This building is used to assemble centrifuges before they are moved into the Separations Building and installed in the cascades. The overall layout of the Centrifuge Assembly Building (CAB) is presented in Figures 1.1-11 through 1.1-13. The Centrifuge Assembly Building is located adjacent to the Cylinder Receipt and Dispatch Building. The major functional areas of the CAB are:

- Centrifuge Component Storage Area
- Centrifuge Assembly Area
- Assembled Centrifuge Storage Area
- Centrifuge Test Facility

- Centrifuge Post Mortem Facility

Source material and SNM are used and produced in this area. Additional details of the Centrifuge Assembly Building are provided in Chapter 3, Integrated Safety Analysis Summary. Administration Building The general office areas and Entrance Exit Control Point (EECP) are located in the Administration Building, Figure 1.1-14, Administration Building. All personnel access to the facility occurs at this location. Vehicular traffic passes through a security checkpoint before being allowed to park. Parking is located outside of the Controlled Access Area (CAA) security fence. Personnel enter the Administration Building and general office areas via the main lobby. Personnel requiring access to facility areas or the CAA must pass through the EECP. The EECP is designed to facilitate and control the passage of authorized facility personnel and visitors.

Entry to the facility area from the Administration Building is only possible through the EECP. Additional details of the Administration Building are provided in Chapter 3, Integrated Safety Analysis Summary. Security Building The main site Security Building is located at the entrance to the plant. It functions as a security checkpoint for incoming and outgoing vehicular traffic. Employees, visitors and trucks that have access approval are screened at this location.

A guard house is located at the secondary site entrance on the west side of the site. Common carriers, such as mail delivery trucks, are screened at this location. Additional details of the Security Building are provided in Chapter 3, Integrated Safety Analysis Summary.

Cylinder Receipt and Dispatch Building The overall layout of the Cylinder Receipt and Dispatch Building (CRDB) is presented in Figures 1.1-15, Cylinder Receipt and Dispatch Building First Floor Part A, and 1.1-16, Cylinder Receipt and Dispatch Building First Floor Part B. The CRDB is located between two Separations Building Modules, adjacent to the Blending and Liquid Sampling Area. This building contains equipment to receive, inspect, weigh and temporarily store cylinders of feed UF₆ sent to the plant; temporarily store, inspect, weigh, and ship cylinders of enriched UF₆ to facility customers; receive, inspect, weigh, and temporarily store clean empty product and UBCs prior to being filled in the Separations Building; and inspect,

weigh, and transfer filled UBCs to the UBC Storage Pad. The functions of the Cylinder Receipt and Dispatch Building are:

- Loading and unloading of cylinders
- Inventory weighing
- Storage of protective cylinder overpacks
- Storage of clean empty and empty UBCs
- Buffer storage of feed cylinders

Source and SNM are used in this area. Additional details of the Cylinder Receipt and Dispatch Building are provided in Chapter 3, Integrated Safety Analysis Summary. Blending and Liquid Sampling Area The Blending and Liquid Sampling Area is adjacent to the CRDB and is located between two Separations Building Modules. The Blending and Liquid Sampling Area is shown in Figure 1.1-17, Blending and Liquid Sampling Area First Floor.

The primary function of the Blending and Liquid Sampling Area is to provide means to fill ANSI N14.1 (ANSI, applicable version) Model 30B cylinders with UF₆ at a required ²³⁵U enrichment level and to liquefy, homogenize and sample 30B cylinders prior to shipment to the customer.

The area contains the major components associated with the Product Liquid Sampling System and the Product Blending System. SNM is used in this area. Additional details on these systems are provided in Chapter 3, Integrated Safety Analysis Summary.

UBC Storage Pad The facility utilizes an area outside of the CRDB, the UBC Storage Pad, for storage of cylinders containing UF₆ that is depleted in ²³⁵U. The cylinder contents are stored under vacuum in corrosion-resistant ANSI N14.1 (ANSI, applicable version) Model 48Y cylinders. The UBC Storage Pad is described in detail in Chapter 3, Integrated Safety Analysis Summary.

The UBC storage area layout is designed for moving the cylinders with a small truck and a crane. A flatbed truck moves the UBCs from the CRDB to the UBC Storage Pad entrance. A double girder gantry crane removes the cylinders from the flatbed truck and places them in the UBC Storage Pad. The gantry crane is

designed to double stack the cylinders in the storage area.

Source material is used in this area. Central Utilities Building The Central Utilities Building (CUB) is shown on Figure 1.1-18, Central Utilities Building. 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, by including roll-up access doors. The Standby Diesel Generator System is discussed in Chapter 3.5.10. The building also contains Electrical Rooms, an Air Compressor Room, a Boiler Room and Cooling Water Facility. Visitor Center A Visitor Center is located outside of the Controlled Access area.

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1.1 FACILITY AND PROCESS DESCRIPTION

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This uranium enrichment plant is based on a highly reliable gas centrifuge process. The plant is designed to separate a feed stream containing the naturally occurring proportions of uranium isotopes into a product stream – enriched in the uranium-235 (^{235}U) isotope and a tails stream – depleted in the ^{235}U isotope.

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% ^{235}U to a UF_6 product, containing ^{235}U enriched up to 5 w/o

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) and transferred to the main process facility, the Separations Building. Separation operations are divided among three Separations Building Modules, each capable of handling approximately one-third of plant capacity. Each Separations Building Module is divided into two Cascade Halls, and each Cascade Hall is comprised of eight cascades. Therefore, the total plant is comprised of 48 cascades. Each Cascade Hall produces enriched UF₆ at a specified assay (w/o_{235U}), so up to six different assays can be produced at one time.

The enrichment process, housed in the Separations Building, is comprised of four major elements: a UF₆ Feed System, a Cascade System, a Product Take-off System, and a Tails Take-off System. Other product related functions include the Product Liquid Sampling and Product Blending Systems. Supporting functions include sample analysis, equipment decontamination and rebuild, liquid effluent treatment and solid waste management. The major equipment used in the UF₆ 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), and heated to sublime the UF₆. The light gases and UF₆ gas generated during feed purification are routed to the Feed Purification Subsystem where the UF₆ is desublimed.

The major pieces of equipment in the Feed Purification Subsystem are UF₆ Cold Traps, a Vacuum Pump/Chemical Trap Set, and a Low Temperature Take-off Station (LTTS). The Feed Purification Subsystem removes any light gases such as air and HF from the UF₆ prior to introduction into the cascades. The UF₆ is captured in UF₆ Cold Traps and ultimately recycled as feed, while HF is captured on chemical traps.

After purification, UF₆ from the Solid Feed Stations is routed to the Cascade System. Pressure in all process lines is subatmospheric. Gaseous UF₆ 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 UF₆ exiting the cascades is 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 UF₆ from the cascades is desublimed in a Product Take-off System comprised of vacuum pumps, Product Low Temperature Take-off Stations (LTTS), UF₆ Cold Traps, and Vacuum Pump/Chemical Trap Sets. The pumps transport the UF₆ from the cascades to the Product LTTS at subatmospheric pressure. The heat of desublimation of the UF₆ 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 UF₆ Cold Trap and Vacuum Pump/Trap Set are provided to vent these gases from the product cylinder. Any UF₆ 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 ²³⁵U). The Product Liquid Sampling Autoclave is an electrically heated, closed pressure vessel used to liquefy the UF₆ 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 UF₆ 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 UF₆ from two donor cylinders of different assays into a product receiver cylinder. The Product Blending System is comprised of Blending Donor Stations for the two donor cylinders and a Blending Receiver Station for the receiver 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.

Support functions, including sample analysis, equipment decontamination and rebuild, liquid effluent treatment and solid waste management are conducted in the Technical Services Building (TSB). Decontamination, primarily of pumps and valves, uses solutions of citric acid.

Sampling includes a Chemical Laboratory for verifying product UF₆ assay, and an Environmental Monitoring Laboratory. Liquid effluent is collected and treated and monitored before discharge to the Treated Effluent Evaporation Basin, a double-lined evaporative basin with leak detection.

Nuclear energy and uranium enrichment

- کتاب «انرژی هسته‌ای و غنی‌سازی اورانیوم» نوشته مهندس رضا بدریان از سوی انتشارات مرسل منتشر شده است.



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