11.0 PLANT SYSTEMS

This chapter describes the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) plant and systems, along with the design basis for each system. In addition, the chapter provides design, operational, and process flow information to support the hazard and accident analysis provided in Chapter 5, as well as to assist in understanding the overall design and function of the MFFF plant and systems. Therefore, both non-principal and principal structures, systems, and components (SSCs) are discussed. Chapter 11 is divided into the following sections:

- Civil Structural Systems (Section 11.1)
- MOX Process Description (Section 11.2)
- Aqueous Polishing Process Description (Section 11.3)
- HVAC Systems and Confinement (Section 11.4)
- Electrical Systems (Section 11.5)
- Instrumentation and Control Systems (Section 11.6)
- Material-Handling Equipment (Section 11.7)
- Fluid Transport Systems (Section 11.8)
- Fluid Systems (Section 11.9)
- Heavy Lift Cranes (Section 11.10)
- Laboratory (Section 11.11)
- Seismic Qualification of Equipment, Systems, and Components (Section 11.12).

The sections of this chapter are generally organized to include the following subsections:

- **Function** – Provides the purpose and functional requirements for each system. Chapter 5 provides the safety function of the principal SSCs associated with each system.
- **Description** – Describes the system, including principal and non-principal SSCs.
- **Major Components** – Provides a list and description of major components.
- **Control Concepts** – Discusses how the system is controlled (i.e., automatically or manually).
- **System Interfaces** – Lists the interfaces with other major systems.
- **Design Basis for Non-Principal SSCs** – Includes a summary of the design basis for the SSCs associated with this system, including non-safety codes and standards applicable to its design. This information is provided to acquaint the reader generally with the design and is not intended to constitute a commitment with respect to the non-safety aspects or functions of the system.
- **Design Basis for Principal SSCs** – Provides the safety basis for the principal SSCs associated with this system and the function, requirement, applicable codes and standards, and design values applied to the principal SSCs. Chapter 5 lists the principal SSCs associated with each system. The assurance measures applicable to the principal SSCs will be described in the Integrated Safety Analysis (ISA) Summary accompanying the license application for possession and use of special nuclear material (SNM).

The majority of this chapter is provided for information to acquaint the reader generally with the design, the details of which are subject to change during detailed design. Where applicable, the subsection entitled "Design Basis for Principal SSCs" constitutes the design basis for that system associated with the safety assessment discussed in Chapter 5. The systems' safety functions, system descriptions, and relationship to the safety assessment are described to the extent supported by information available in the preliminary design. Modifications to the design and additional features will be described in the ISA Summary.

Table 11.0-1 lists the designations used to identify the various buildings and systems presented in Chapter 11.

Tables

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Table 11.0-1. Building and System Designations

System	Designation
Buildings	
MFFF Building	BMF
Aqueous Polishing Area	BAP
Emergency Generator Building	BEG
Safe Haven Buildings	BSH
Secured Warehouse Building	BSW
Standby Generator Building	BSG
MOX Fuel Fabrication Area	BMP
Shipping and Receiving Area	BSR
Reagent Processing Building	BRP
Administration Building	BAD
Technical Support Building	BTS
Aqueous Polishing Units	
Decanning Unit	KDA
Milling Unit	KDM
Recanning Unit	KDR
Dissolution Unit	KDB
Dechlorination and Dissolution Unit	KDD
Purification Cycle	KPA
Solvent Recovery Cycle	KPB
Oxalic Precipitation and Oxidation Unit	KCA
Homogenization Unit	KCB
Canning Unit	KCC
Oxalic Mother Liquor Recovery Unit	KCD
Acid Recovery Unit	KPC
Offgas Treatment Unit	KWG
Liquid Waste Reception Unit	KWD
Uranium Oxide Dissolution Unit	KDC
Sampling System	
MOX Processing Units – Receiving Area	
UO_2 Receiving and Storage Unit	DRS
UO_2 Drum Emptying Unit	DDP
PuO_2 Receiving Unit	DCP
PuO_2 3013 Storage Unit	DCM
PuO_2 Buffer Storage Unit	DCE
MOX Processing Units – Powder Area	
PuO_2 Can Receiving and Emptying Unit	NDD
Primary Dosing Unit	NDP
Primary Blend Ball Milling Unit	NBX
Final Dosing Unit	NDS
Powder Auxiliary Unit	NXR

Table 11.0-1. Building and System Designations

System	Designation
Scrap Processing Unit	NCR
Jar Storage and Handling Unit	NTM
Homogenization and Pelletizing Units	NPE, NPF
Scrap Ball Milling Unit	NBY
Sintering Units	PFE, PFF
Grinding Units	PRE, PRF
Quality Control and Manual Sorting Unit	PQE
Pellet Repackaging Unit	PAD
Scrap Box Loading Unit	PAR
Green Pellet Storage Unit	PSE
Sintered Pellet Storage Unit	PSF
Scrap Pellet Storage Unit	PSI
Ground and Sorted Pellet Storage Unit	PSJ
Pellet Handling Unit	PML
Pellet Inspection and Sorting Units	PTE
MOX Processing Units – Fuel Rod Process Area	
Rod Cladding and Decontamination Unit	GME, F
Rod Tray Loading Unit	GMK
Rod Decladding Unit	GDE
X-Ray Inspection Units	SXE, SXF
Helium Leak Test Unit	SEK
Rod Inspection and Sorting Unit	SDK
Rod Scanning Unit	SCE
Rod Storage Unit	STK
MOX Processing Units – Assembly Area	
Assembly Mockup Loading Unit	TGM
Assembling Mounting Unit	TGV
Assembly Handling and Storage Unit	TAS
Assembly Dry Cleaning Unit	TCK
Assembly Dimensional Inspection Unit	TCP
Assembly Final Inspection Unit	TCL
Assembly Packaging Unit	TXE
MOX Processing Units – Waste Handling Areas	
Filter Dismantling Unit	VDR
Maintenance and Mechanical Dismantling Unit	VDU
Waste Storage Unit	VDQ
Waste Nuclear Counting Unit	VDT
Mechanical Utility Systems	
HVAC Chilled Water System	CHH
Process Chilled Water System	CHP
Demineralized Water System	DMW
Process Hot Water System	HWS

Table 11.0-1. Building and System Designations

System	Designation
Process Steam and Process Condensate Systems	SPS and SPC
Plant Water System	PWS
Emergency Generator Fuel Oil System	EGF
Standby Generator Fuel Oil System	SGF
Service Air System	SAS
Instrument Air System	IAS
Breathing Air System	BAS
Radiation Monitoring Vacuum System	VRM
Bulk Gas Systems	
Nitrogen System	GNS
Argon/Hydrogen System	GAH
Helium System	GHE
Oxygen System	GOX
Reagent Systems	
Nitric Acid System	RNA
Silver Nitrate System	RSN
Tributyl Phosphate System	RTP
Hydroxylamine Nitrate System	RHN
Sodium Hydroxide System	RSH
Oxalic Acid System	ROA
Diluent System	RDO
Sodium Carbonate System	RSC
Hydrogen Peroxide System	RHP
Hydrazine System	RHZ
Manganese Nitrate System	RMN
Decontamination System	DCS
Nitrogen Oxide System	GNO
HVAC Systems	
Very High Depressurization Exhaust System	VHD
High Depressurization Exhaust System	HDE
Medium Depressurization Exhaust System	MDE
Process Cell Exhaust System	POE

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11.1.7.3 Codes and Standards for SC-I Structures

Codes and standards applied to the MFFF include the following:

American Concrete Institute (ACI)

- ACI-224R-90, *Control of Concrete Cracking in Concrete Structures*
- ACI-301-99, *Standard Specifications for Structural Concrete*
- ACI-315-99, *Details and Detailing of Concrete Reinforcement*
- ACI-336.2R-88, *Suggested Analysis and Design Procedures for Combined Footings and Mats*
- ACI-349-97, *Code Requirements for Nuclear Safety-Related Concrete Structures & Commentary*
- ACI-349.1R-91, *Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures*, Reapproved 1996
- ACI-351.1R-99, *Grouting for Support of Equipment & Machinery*
- ACI-352R-91, *Recommendations for Design of Beam-Column Joints in Monolithic Reinforced Concrete Structures*, Reapproved 1997
- ACI-352.1R-89, *Recommendations for Design of Slab-Column Connections in Monolithic Reinforced Concrete Structures*, Reapproved 1997
- ACI-349-01, Appendix B, *Anchoring to Concrete* (for anchoring to concrete only)
- ACI-360R-92, *Design of Slabs on Grade*, Reapproved 1997
- ACI-351.2R-94, *Foundations for Static Equipment*
- ACI-439.3R-91, *Mechanical Connections of Reinforcing Bars*
- ACI-SP-152-95, *Design and Performance of Mat Foundations*

- ACI-503R-93, *Use of Epoxy Compounds with Concrete*
- ACI-442-88, *Response of Concrete Buildings to Lateral Forces*
- ACI-207.1R-96, *Mass Concrete*
- ACI-207.2R-95, *Effect of Restraint, Volume Change, and Reinforcement on Cracking of Mass Concrete*
- ACI-207.4R-93, *Cooling and Insulating Systems for Mass Concrete.*

American Institute of Steel Construction (AISC)

- AISC ASD, *Manual of Steel Construction, Allowable Stress Design*, 9th Edition, 1989
- ANSI/AISC N690-1994, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities*
- AISC, *Seismic Provisions for Structural Steel Buildings*, April 1997.

American Society of Civil Engineers (ASCE)

- ASCE Standard 4-98, *Seismic Analysis of Safety Related Nuclear Structures*
- ASCE Standard 7-98, *Minimum Design Loads for Buildings and Other Structures*
- ASCE Standard 8-91, *Specification for the Design of Cold-Formed Stainless Steel Structural Members.*

American Welding Society (AWS)

- AWS-D1.1-98, *Structural Welding Code – Steel*, 1998
- NCIG-01, *Visual Weld Acceptance Criteria for Structural Welding of Nuclear Power Plants*, Revision 2, EPRI NP-5380.

American Association of State Highway and Transportation Officials (AASHTO)

- *Standard Specifications for Highway Bridges*, Sixteenth Edition, 1996.

American National Standards Institute (ANSI)

- ANSI N101.4, *Quality Assurance for Protective Coatings Applied to Nuclear Facilities*, 1972.

American Iron and Steel Institute (AISI)

- AISI, *Specifications for the Design of Cold-Formed Steel Structural Members*, 1986.

American Society for Testing and Materials (ASTM)

- Research Council on Structural Connections, *Specification for Structural Joints Using ASTM A325 and A490 Bolts*, June 23, 2000.

Code of Federal Regulations (CFR)

- 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*
- 10 CFR Part 73, *Physical Protection of Plants and Materials.*

SRS Engineering Standards Manual (WSRC-TM-95-1)

- Engineering Standard No. 01060, *Structural Design Criteria*, Revision 4, dated September 1999
- Engineering Standard No. 01110, *Civil Site Design Criteria*, Revision 3, dated April 11, 2000.

U.S. Nuclear Regulatory Commission (NUREG)

- NUREG-0800, Standard Review Plan 3.5.3, *Barrier Design Procedures*, July 1981
- NUREG-0800, Standard Review Plan 3.8.4, *Other Seismic Category I Structures*, July 1981
- NUREG-0800, Standard Review Plan 3.5.1.6, *Aircraft Hazards*, April 1996.

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Table 11.1-2. Summary of MFFF Site Design Criteria

Criterion	Value
Severe Wind (SC-I and SC-II)	Three-second wind speed: 130 mph Missile criteria: 2- by 4-inch timber plank, 15 lb at 50 mph (horizontal); max. height 50 ft (see Note 1)
Extreme Wind/Tornado (Wind Loads) (SC-I)	Three-second wind speed: 240 mph Atmospheric pressure change: 150 psf at 55 psf/sec Rate of pressure drop: 55 psf/sec
Tornado Missile Spectrum (SC-I)	<u>2- by 4-inch timber plank</u> Mass: 15 lb Horizontal Impact Speed: 150 mph Vertical Impact Speed: 100 mph Maximum Height: 200 ft <u>3-inch diameter standard steel pipe</u> Mass: 75 lb Horizontal impact speed: 75 mph Vertical impact speed: 50 mph Maximum height: 100 ft <u>3000-lb automobile</u> Horizontal impact speed: 25 mph, rolls and tumble
Wind (CS)	Basic winds: 107 mph (Note 1)
Floods	Design flood level (DFL)above MSL: 207.9 ft Probable maximum flood level (PMF) above MSL: 224.5 ft Site grade level ≈ 272 ft above msl
Precipitation (SC-I)	Accumulative precipitation: Fifteen minutes: 3.9 inches One hour: 7.4 inches Three hours: 14.1 inches Six hours: 16.7 inches Twenty-four hours: 22.7 inches
Snow and Ice Loads (SC-I)	Snow/ice loading: 10 lb/ft² Exposure factor: 1.0 Snow drift is considered in the design For SC-I and SC-II , Importance factor = 1.2
Seismic (Ground Motion) (SC-I and SC-II)	Regulatory Guide 1.60 scaled to 0.20g peak ground acceleration
Foundation Design Bearing Pressure	(see Section 11.1.7.2.2.3)
Groundwater	Maximum groundwater elevation above msl: 210.0 ft.
Explosions	(see Section 11.1.7.4.1.3)
Aircraft Impact	(Not a design basis event, see Section 11.1.7.4.1.3)
Range Fires	(Not a design basis event, see Section 11.1.7.4.1.3)

Note 1: For determining wind loads using the ASCE 7-98 procedure, the following definitions apply: I = 1.15 (SC-I and SC-II), I = 1.0 (CS); Exposure Category = C; K_{zt} = 1.0; and K_d = 1.0.

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11.2 MOX PROCESS DESCRIPTION

This section provides a description and overview of the MOX Process (MP), including design, operational, and process flow information. This information is provided to support the hazard and accident analysis provided in Chapter 5, as well as to assist in understanding the overall design and function of the MOX Process.

11.2.1 Function

The MP Area receives polished PuO_2 from the aqueous polishing (AP) process, UO_2 depleted in ^{235}U, and the required components for assembling light-water reactor (LWR) MOX fuel assemblies. The process mixes the plutonium and uranium oxides to form MOX fuel pellets. The pellets are loaded into fuel rods, which are then assembled into MOX fuel assemblies for use in commercial reactors. The MP Area is designed to process up to 70 MtHM annually. The safety functions of the principal SSCs associated with the MP process are discussed in Chapter 5.

11.2.2 Description

The MFFF uses the A-MIMAS process for the manufacture of MOX fuel assemblies. A-MIMAS (advanced MIMAS) represents the latest evolution of the successive MIMAS fabrication processes adopted by BELGONUCLEAIRE and COGEMA to produce MOX fuel pellets. A-MIMAS uses a two-step mixing process. In the first step, the PuO_2 powder is mixed with depleted UO_2 and recycled scrap powder to form a primary blend (master blend) with a nominal PuO_2 content of 20% of the total mass. This mix is then micronized. In the second step, the primary blend is forced through a sieve and poured into a jar and mixed with depleted UO_2 and scrap powder to obtain the final blend with the specified plutonium content. The nominal PuO_2 content in the final blend is nominally 6% of the total mass. The two-step mixing process is used to ensure a consistent product.

The MP process consists of five process areas divided into individual process units or systems (see Figure 11.2-1). This section also includes a description of associated waste process units.

<u>Receiving Area</u> – This area includes truck unloading, PuO_2 container handling, counting, and storage before and after transfer to the AP line. The function of the Receiving Area is to receive, unload, and store PuO_2 and UO_2 powder. The Receiving Area is composed of the following units:

- UO_2 Receiving and Storage Unit
- UO_2 Drum Emptying Unit
- PuO_2 Receiving Unit
- PuO_2 3013 Storage Unit
- PuO_2 Buffer Storage Unit.

Powder Area – This area has equipment for dosing MOX powder at the specified plutonium content in two steps, for homogenizing and for pelletizing. The Powder Area receives UO_2 and PuO_2 powders and produces a mixture of specific plutonium content suitable for the production of MOX fuel pellets. The Powder Area is composed of the following units:

- PuO_2 Can Receiving and Emptying Unit
- Primary Dosing Unit
- Primary Blend Ball Milling Unit
- Final Dosing Unit
- Homogenization and Pelletizing Units
- Scrap Processing Unit
- Scrap Ball Milling Unit
- Powder Auxiliary Unit
- Jar Storage and Handling Unit.

Pellet Process Area – In this area, MOX pellets are sintered, ground, and sorted. The function of the Pellet Process Area is to receive, store, process, and handle fuel pellets. The Pellet Process Area is composed of the following units:

- Green Pellet Storage Unit
- Sintering Units
- Sintered Pellet Storage Unit
- Grinding Units
- Ground and Sorted Pellet Storage Unit
- Pellet Inspection and Sorting Units
- Quality Control and Manual Sorting Unit
- Scrap Box Loading Unit
- Pellet Repackaging Unit
- Scrap Pellet Storage Unit
- Pellet Handing Unit.

Fuel Rod Process Area – In this area, pellets are loaded into rods and the rods are inspected. The function of the Fuel Rod Process Area is to assemble, inspect, and store fuel rods. The Fuel Rod Process Area is composed of the following units:

- Rod Cladding and Decontamination Unit
- Rod Tray Loading Unit
- Rod Storage Unit
- Helium Leak Test Unit
- X-Ray Inspection Units
- Rod Scanning Unit
- Rod Inspection and Sorting Unit
- Rod Decladding Unit.

Assembly Area – In this area, rods are loaded into assemblies and the assemblies are inspected and stored. The functions of the Assembly Area are to receive fuel rods and the required fuel assembly components and to assemble, inspect, and store completed MOX fuel assemblies. The Assembly Area is composed of the following units:

- Assembly Mockup Loading Unit
- Assembly Mounting Unit
- Assembly Dry Cleaning Unit
- Assembly Dimensional Inspection Unit and Assembly Final Inspection Unit
- Assembly Handling and Storage Unit
- Assembly Packaging Unit.

Waste Area – In this area, solid radioactive waste generated during the MOX process is processed, stored and packaged for shipment. The Waste Area is composed of the following units:

- Filter Dismantling Unit
- Maintenance and Mechanical Dismantling Unit
- Waste Storage Unit
- Waste Nuclear Counting Unit

The MOX process is shown in Figure 11.2-1. Block diagrams of the MOX process are provided in Figures 11.2-2 and 11.2-3. Table 5.5-3 lists the radioactive inventory for each facility location.

11.2.2.1 UO_2 Receiving and Storage Unit

The function of the UO_2 Receiving and Storage Unit is to receive and store depleted UO_2 for use in the manufacture of MOX fuel assemblies. Storage facilities consist of the external Secured Warehouse Building and a UO_2 buffer storage room within the MOX Process Area of the MOX Fuel Fabrication Building. The Secured Warehouse Building is located adjacent to the MOX Fuel Fabrication Building. UO_2 is delivered to the Secured Warehouse Building in palletized drums. Within the drums, the uranium is contained in double vinyl bags, separately sealed, under a nitrogen atmosphere. The drums are placed within the Secured Warehouse Building for temporary storage. When required, drums are transferred to the MOX Process Area. The drums are staged in a buffer storage area in close proximity to the UO_2 drum emptying room.

The major equipment associated with this unit is the pallet truck and forklift.

The UO_2 Receiving and Storage Unit interfaces with the UO_2 Drum Emptying Unit and the MMIS system with its embedded Material Control and Accounting (MC&A) application.

11.2.2.2 UO_2 Drum Emptying Unit

The function of the UO_2 Drum Emptying Unit is to open UO_2 drums and vinyl bags and pour the contents into a UO_2 receiving hopper in full confinement conditions. The unit controls UO_2

powder feeding to the dosing units. All incoming and outgoing UO_2 drums from the drum storage room are identified and weighed.

In addition, powder samples can be taken. When a powder sample is taken, the vial is identified and weighed before being sent manually to the lab.

The major equipment associated with this unit is as follows (Figure 11.2-4):

- Drum buffer storage
- Data acquisition keyboard and display system with manual bar code reader for drum identification
- Drum Scale
- Pallet truck
- Drum-tilting device and associated storage
- Handling monorails
- Two pouring stations with associated glovebox, funnels, and UO_2 receiving hopper
- Feeding lines and control valves
- Collection station for the empty vinyl bags and desiccant
- Scale and its associated bar code reader for sample vials.

As necessary, a provision of full drums is transferred from the warehouse into the buffer storage area. A drum is manually transferred from the buffer storage area to the UO_2 drum emptying room where the drums are identified and weighed. The UO_2 powder is emptied into the UO_2 receiving hopper.

The UO_2 Drum Emptying Unit interfaces with both the Primary and Final Dosing Units.

11.2.2.3 PuO_2 Receiving Unit

The PuO_2 Receiving Unit is located in the MOX Fuel Fabrication Building. It receives and opens PuO_2 shipping packages. The PuO_2 3013 Storage Unit is located in the MOX Process Area and transfers 3013 containers from the shipping package to a 3013 storage pit. The unit also performs required nuclear assay, container weighing, identification, and tracking functions.

The major equipment associated with these units is as follows:

- Cargo restraint transporter (CRT)
- Shipping package (SAFKEG or 9975 type)
- Monorail cranes
- Cask and containment vessel opening stations
- Powered conveyors and turntables
- 3013 container
- Transfer cask
- Traveling crane
- Multiplier counter and gamma isotopic analysis system

- Scale
- Calorimeter
- 3013 storage pit and associated shield plug
- 3013 storage area overhead bridge crane.

PuO_2 is delivered to the MOX Fuel Fabrication Building at the Shipping and Receiving Area in shipments by a Safe Secure Transport (SST) or Safeguard Transport (SGT) vehicle. The SST/SGT vehicle contains casks palletized on CRTs. Several shipping package (SAFKEG or 9975 type) are loaded on each CRT, and several CRTs are loaded on each truck.

Each shipping package is composed of a nest of containers as follows:

- External physical, thermal, and radiation protection vessel
- Secondary containment vessel
- Primary containment vessel with the 3013 container.

Each shipping package contains one 3013 container, which is also a nest of an outer can, an inner can, and a convenience can (Figure 11.2-5).

The CRTs are removed from the SST/SGT by a forklift and transferred from the truck dock to a process room located in the MOX Process Area where they are stored behind shielding panels. There, one at a time, each shipping package is removed from the CRT and then moved to the shielded package buffer storage unit. During SST/SGT vehicle receipt and CRT unloading, security inspections, package identification, and health protection controls are performed. Accountability data are logged in the MC&A application embedded in the MMIS system.

Upon demand, each package is opened by removing and storing the external cask plug (physical, thermal, and radiation protection) with the bracket hoist. The monorail hoist is then used to remove the secondary containment vessel, the secondary containment vessel plug, the primary containment vessel, and the primary containment vessel plug. The 3013 container is then removed to a transfer cask. Smear tests are performed for radioactive contamination at the appropriate steps. These operations are reversed to send back an empty cask. All operations are manual but workers are protected by shielding giving access to the top of the packs only.

Following 3013 container removal, a powered conveyor system drives the final 3013 container in a shielded transfer cask to the measuring room. The measuring room contains the following assay instruments:

- Calorimeters
- Coincidence neutron counter
- Weight scale
- Gamma spectrometer system.

The 3013 container is removed from the shielded transfer cask on the conveyor to a calorimeter station. The transfer cask is returned empty to the package opening room to receive the next container. The container is then moved to the neutron measurement station, weighed, and gamma counted. When all measures are completed, the container is placed in a buffer position of the nearby storage area.

After measurements are compared with the relevant shipper's data, the operator authorizes the container to be stored in the "ready to use" storage position or a "quarantine" position waiting for special actions.

The PuO_2 Receiving unit interfaces with the transport vehicles delivering the PuO_2 transportation casks and with the outer and inner 3013 can opening glovebox, which is part of the AP Decanning Unit, described in Section 11.3.

11.2.2.4 PuO_2 3013 Container Storage

The container storage area is comprised of lateral slabs of concrete lined with steel. Steel pits designed to hold the 3013 containers are suspended from the slabs. Each pit is closed by a shield plug constructed of steel-lined concrete. The plug sits flush with the concrete slab.

The storage area is arranged in a 36- by 12-pit array for a total of 430 pits; two pits are reserved for 3013 container transfer. Four 3013 containers can be placed in each pit for a total of 1,720 containers. The pits are designed with 2-ft (0.6-m) centers in both the X and Y dimensions.

The storage area is ventilated by an air stream forced between the steel pits to remove heat generated by the containers. Plenums at both ends of the array distribute the air stream under the slab.

The PuO_2 3013 Storage Unit interfaces with the PuO_2 Receiving Unit.

11.2.2.5 PuO_2 Buffer Storage Unit

The function of the PuO_2 Buffer Storage Unit is to store polished PuO_2 cans received from the AP Canning Unit (see Section 11.3.2.7). The unit also transfers cans of polished PuO_2 to the PuO_2 Can Receiving and Emptying Unit, receives and stores empty cans, transfers them back to the AP PuO_2 Canning Unit, and return cans with rejected powder (if any) back to the Milling Unit ahead of AP for a re-polishing process. The PuO_2 Buffer Storage Unit separates the AP Area from the MP Area and acts to buffer the variations in the throughput capacities of the AP and MP Areas.

Purified plutonium from the AP process is transferred in reusable cans whose outer surfaces may be contaminated. For this reason, the PuO_2 Buffer Storage Unit is installed in a glovebox, and cans are transferred from AP via a pneumatic transfer system to this unit. All normal operations within the transfer and storage gloveboxes are performed remotely. The PuO_2 Buffer Storage Unit is able to accommodate up to 399 cans in two rows of 26 wells and three rows of 27 wells with three cans stacked in each well.

The major equipment associated with this unit is as follows (Figure 11.2-6):

- Transfer glovebox
- Buffer storage glovebox

- PuO_2 can storage array
- Handling crane
- Precision scale.

Polished PuO_2 is transferred to the transfer glovebox from the AP PuO_2 Canning Unit via a pneumatic transfer tube and a shuttle. Upon arrival, the transfer shuttle is removed from the receiving section and opened. The PuO_2 can is removed from the shuttle and placed on the precision scale for weighing and identification. The PuO_2 can may be either sent directly to the PuO_2 Can Receiving and Emptying Unit or transferred to the storage glovebox, or returned to the AP Milling Unit when the can contains PuO_2 powder that is out of specifications. Empty PuO_2 cans are returned from the PuO_2 Can Receiving and Emptying Unit for transfer to the storage glovebox or transfer to the AP PuO_2 Canning Unit for reuse. The empty cans are also weighed and identified.

The storage glovebox contains an array of storage compartments, each capable of holding three full or empty PuO_2 cans. The compartments are closed with a shield plug. A handling crane within the glovebox removes the shield plug and places/removes cans into/from the storage compartment and replaces the plug.

The PuO_2 Buffer Storage Unit interfaces with the AP PuO_2 Canning Unit, the PuO_2 Can Receiving and Emptying Unit, the AP Milling Unit and the MMIS system with its embedded MC&A application.

11.2.2.6 PuO_2 Can Receiving and Emptying Unit

The function of the PuO_2 Can Receiving and Emptying Unit is to receive cans of purified PuO_2 and empty the cans onto a vibrating conveyor supplying the Primary Dosing unit. The unit also performs can weighing and identification. In addition, the unit accommodates can maintenance and removal of used or damaged cans and lids as well as the introduction of new cans and lids.

These functions are performed in four gloveboxes: the can receiving glovebox, the can emptying glovebox, the connection glovebox, and the transfer glovebox. The major equipment associated with this unit is as follows (Figure 11.2-7):

- Can receiving glovebox
  - Pneumatic transfer end station
  - Shuttle handling
  - Can handling
  - Precision scale and identification station (MC&A)
  - PuO_2 can storage
  - Atmospheric change airlock
  - Maintenance trolley

- Can emptying glovebox
  - Can handling
  - Precision scale and identification station
  - Can opening/closing device

- Emptying flywheel with impactor
- PuO_2 collecting funnel
- Vacuum cleaning station with manual can opening device

- Connection glovebox with vibrating channel

- Transfer glovebox with manual gripper and bag port to transfer PuO_2 cans and lids.

PuO_2 cans are received in the can receiving glovebox via a pneumatic transfer tube from the PuO_2 Buffer Storage Unit. The cans are removed from the transfer shuttle, weighed, and identified. Shuttles and PuO_2 cans are moved within the glovebox by means of conveyors. A can is placed on the can elevator and moved into the atmospheric change airlock. This airlock allows transfer between the dry air atmosphere of the receiving glovebox and the nitrogen atmosphere of the can emptying glovebox. The can receiving glovebox provides temporary storage for five PuO_2 cans.

In the can emptying glovebox, the can is weighed and identified. The can opening/closing device and associated gripper then remove the PuO_2 can lid. The conveyor transfers the can to the emptying station, which moves the can up and docks the PuO_2 can to the emptying flywheel. The emptying flywheel rotates, and the PuO_2 is transferred by gravity into the connection glovebox vibrating channel. The collecting funnel impactor is started to ensure that all the PuO_2 flows into the vibrating channel. The PuO_2 is transferred to the dosing station in the primary dosing glovebox. The can is placed back on the conveyor, the lid is placed on the can, and the can is weighed and identified. The can is moved back into the receiving glovebox through the atmospheric change airlock and placed in its position on the storage rack of the receiving glovebox. The empty PuO_2 cans are weighed, identified, placed in a shuttle, and returned to the PuO_2 Buffer Storage Unit via the pneumatic transfer system. PuO_2 can emptying cycles are completed according to the number of cans required to constitute one primary dosing jar.

Replacement of PuO_2 cans becomes necessary when cans are used for a specified number of filling and emptying operations. At the end of the emptying cycle, the empty can to be replaced is weighed and identified, then de-dusted using the dust collection system of the Primary Dosing Unit. The can is then closed and sent back into the receiving glovebox to the maintenance trolley. The trolley is moved to the receiving glovebox door, which is manually opened. The can is manually moved into the transfer glovebox, and the glovebox door is shut. Used cans and lids are removed through the transfer glovebox bag port. New cans are introduced to the transfer glovebox through the bag port and moved into the receiving glovebox. All operations in the transfer glovebox are performed manually.

The PuO_2 Can Receiving and Emptying Unit interfaces with the primary dosing glovebox, the PuO_2 Buffer Storage Unit, the MMIS system with its embedded MC&A application, and the control display in the control room.

11.2.2.7 Primary Dosing Unit

The function of the Primary Dosing Unit is to prepare a J60 jar with a UO_2-PuO_2 powder blend called "primary blend" or "master blend." A J60 jar is a container which holds a nominal 60 kg of primary blend powder. The nominal PuO_2 content of the primary blend is 20%. The blend is made of a mixture of polished PuO_2 from the AP process, UO_2 powder, and micronized scrap powder.

The major equipment associated with this unit is as follows (Figure 11.2-8):

- Connection module (i.e., jar lid removal, jar weighing, and bar code reader identification systems)
- Jar elevator with two tilting devices
- Conveyor system
- Dosing scale and associated electronics
- TV cameras
- Dust collection equipment
- Magnetic catcher
- Small funnel for additive in an enclosure
- Frame to support the components
- Maintenance crane.

The primary blend preparation process consists of successively introducing the following:

- Recyclable scrap powder stored in a hopper fed from a J60C jar coming from the Jar Storage and Handling Unit
- PuO_2 powder transferred to the internal jar by a vibrating conveyor from the PuO_2 Container Opening and Handling Unit. The required quantity of PuO_2 powder to be transferred is controlled by weighing the PuO_2 cans and the internal jar.

  UO_2 powder from a main hopper fed by the UO_2 Drum Emptying Unit. The powder is transferred to the inner jar via a pre-dosing hopper.

As for the other powder process units, during normal operation the process is fully automatic and supervised by an operator from the control room. However, a few manual operations may be necessary during normal operation:

- Handling incoming empty dust pots from the round basket holding five pots
- Weighing and identifying the empty dust pots
- Connecting the pot to the dust collector
- Weighing and identifying full pots
- Loading five pots into a round basket
- Calibrating the scale with standard weights.

The sequence of the main operations is as follows. A program computes the required amounts of powder and identifies the containers holding them, taking into consideration the target enrichment, weights, and characteristics of the available powders. These values are introduced into the programmable logic controller (PLC) at the beginning of the sequence. UO_2 feeding of the receiving hopper is performed independently according to the signals from the high- and low-level detectors.

The jar is sent back to the connection module to be weighed, and identified and then to Jar Storage and Handling Unit for storage.

Similarly, the necessary PuO_2 pots are transferred to the PuO_2 Container Opening and Handling Unit.

The unit is now ready for primary dosing.

The PuO_2 of several cans is transferred from the PuO_2 Container Opening and Handling Unit to the vibrating conveyor and poured into the internal jar.

The powders are emptied from the collecting funnel using an impactor between each product to ensure accurate control of the weights on the dosing scale.

A J60 jar in the Jar Storage and Handling Unit is transferred to the unit through the connection module where it is weighed and identified before being transferred to beneath the mixer.

The Primary Dosing Unit interfaces with the Jar Storage and Handling Unit, the UO_2 Drum Emptying Unit, the PuO_2 Can Receiving and Emptying Unit, and the MMIS system with its embedded MC&A application. The unit has its own supervisory system in the control room.

11.2.2.8 Primary Blend Ball Milling Unit

The function of the Primary Blend Ball Milling Unit is to micronize the primary blend (master blend). The ball mill is composed of a cylindrical steel vessel into which the powder to be milled is emptied. The ball mill is located in a dedicated glovebox with a connection to the Jar Storage and Handling Unit.

The major equipment associated with this unit is as follows (Figure 11.2-9):

- Connection module
- Conveyor system
- Jar Elevator
- Clamping device
- Mill drum with bearing and tilting support
- Rotational and tilting drive system
- Frame to support the two drive systems and the ball mill
- Glovebox
- Handling device.

A J60 jar selected for ball milling is brought into the ball milling glovebox from the Jar Storage and Handling Unit via the connection module. This module is standardized and links the Jar Storage and Handling Unit to each powder production station. A gear-driven roller conveyor transfers the jar container from the Jar Storage and Handling Unit. The lid is removed from the jar, and the jar is weighed and identified.

The conveyor then moves the jar into the ball milling glovebox and positions the jar over an elevator. The elevator raises the jar, and a jar-clamping device secures the jar to the docking flange of the ball mill. The mill is turned upside down to transfer the powder into it.

As the vessel rotates slowly, the balls fall against one another and the vessel, milling the powder between them. After milling, the mill turns right side up to empty the powder into the J60 jar, the jar is disconnected, lowered into its shielded cask. The jar is then weighed, identified, and it's lid reinstalled and then transferred to the Jar Storage and Handling Unit for storage until it is transferred to the Final Dosing Unit.

Manual operations include glovebox cleaning and crane handling for maintenance.

The ball mill is interconnected with the Jar Storage & Handling Unit and the MMIS system with its embedded MC&A application. It has its own monitoring system in the control room.

11.2.2.9 Final Dosing Unit

The Final Dosing Unit prepares the final MOX blend with a specified plutonium content for fuel pellet manufacture. UO_2 powder, micronized primary blend, and recyclable scrap powder from scrap milling are utilized in the unit with a nominal PuO_2 content in the blend of 6%. The final dosing process is performed in a dedicated glovebox with a connection to the Jar Storage and Handling Unit. The final blend is prepared in a J80 jar, which holds a nominal 80 kg of final blend powder, on a precision scale.

The major equipment associated with this unit is as follows (Figure 11.2-10):

- Connection module
- Two jar elevators and their tilting devices
- Conveyor system
- Dosing scale

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- Scrap powder line with the same equipment
- TV cameras
- Dust collection network
- Frame to support the components
- Glovebox.

[ ]

Upon the operator's request, a primary blend or scrap jar and associated cask are transferred from the Jar Storage and Handling Unit to the production station. The jar is opened, identified, and weighed in the connection module. The contents of the jar are poured into a weighed receiving hopper. Once emptied, the jar returns to the Jar Storage and Handling Unit via the connection module where it is weighed again and the lid is reinstalled.

Upon the operator's request, an empty J80 jar in its cask is transferred from the Jar Storage and Handling Unit to the Final Dosing Unit. The jar is stopped in the connection module, identified, lid removed, weighed, and transferred to the production station. At this stage, the jar is ready to be filled.

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The precision scale on which the J80 jar stands sends jar weight information to the controller which performs the dosing operation. Vibrating conveyors successively transfer the different products to a collecting funnel, directing the powders into the jar under continuous control of the scale. The scale automatically stops the vibrating conveyor when the required amount of powder is reached and closes the inlet valve.

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Upon cycle completion, the jar is returned to the Jar Storage and Handling Unit via the connection module where it is weighed, identified, and the lid is returned. The cycle is fully automated.

The Final Dosing Unit interfaces with Jar Storage and Handling Unit, the UO_2 Drum Emptying Unit and the mass control system. It also has its own supervisory system in the control room.

11.2.2.10 Homogenization and Pelletizing Unit

The main functions of the Homogenization and Pelletizing Unit are to prepare a homogenized lot of final blend, to add poreformer to obtain pellets with the required specific gravity after sintering, to add lubricant for lubrication of press punches and dies, and finally to press the powder to obtain green cylindrical pellets.

Two identical units are installed to reach the required throughput. Each unit is made up of the following gloveboxes:

- Connection module to the Jar Storage and Handling Unit
- Process glovebox
- Additives introduction glovebox
- Maintenance glovebox
- Press feeding glovebox
- Press glovebox
- Boat loading glovebox
- Filtration glovebox.

The major equipment associated with this unit is as follows (Figure 11.2-11):

- Connection module
- [Jar handling with its conveyor, lift, jar tilter, and]
- Additive feeding station with stearate (lubricant) hopper, vibrating conveyor, and poreformer hopper

[ ]

- Press shoe and associated hoses
- Powder recovery hopper
- Pellet press and associated hydraulic units, a process control cabinet, and an alternative filling shoe
- Boat loading system, with notch conveyor, pellet pusher, filling spout, boat scale, and boats
- Mo-boat handling system, with conveyor system, turntable, boat lift, identification equipment, and scale
- Pellet inspection stand with pellet manipulator, precision scale, length measurement bench, and rotating rollers

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- Powder filtration glovebox, with manual dust pot conveyor, manual pot opener, scale, vacuum extractor, decloggable filter set with powder receiving hopper, pot filling station, and vacuum cleaning lines.

The process is fully automated and supervised by an operator from the control room. However, a few manual operations are necessary during normal operation:

- Introduction of additives
- Pneumatic transfer switching operations
- Dust pot handling
- Waste cask loading operations
- Emptying of the powder recovery hopper
- Visual inspection of sampled pellets.

Prior to introducing the first jar of the lot to be processed, an operator manually loads the additive hoppers using pre-weighed bags of lubricant and poreformer. The automated filling and mixing cycle is then started.

Jars of MOX powder are introduced by conveyor from the Jar Storage and Handling Unit to the connection module where the jar lid is removed and the jar is weighed and identified. The jar is then conveyed to the jar elevator where it is lifted into position and gripped by the jar tilter. The jar is tilted, the contents are emptied onto the vibrating conveyor, and the jar is impacted to ensure the removal of the jar's contents. The conveyor transfers the MOX powder to the mixer. The jar is returned to the Jar Storage and Handling Unit via the connection module where it is again weighed, identified and the lid reinstalled. This operation is repeated until the required quantity of MOX powder is transferred to the mixer.

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Zinc stearate is added, and mixing is continued.

At the lot end, the press shoe is emptied and any remaining powder is sent to the recovery hopper.

The Homogenization and Pelletizing Unit interfaces with the Jar Storage and Handling Unit on one side and with the Green Pellet Storage Unit on the other, and the MMIS system with its embedded MC&A application. The Homogenization and Pelletizing Unit has its own monitor in the control room.

11.2.2.11 Scrap Processing Unit

The Scrap Processing Unit functions to recycle plutonium-containing waste scrap[1] generated in the process of MOX fuel fabrication. This unit is utilized to satisfy the MFFF process goal that the outgoing plutonium flow (contained in fuel rods) be at least 99.5% of the incoming flow.

Scrap consists of discarded sintered pellets, pellet chips, discarded green MOX powder, and dirty powder collected in pots. Dirty powder collected in pots could hold grinding dust with pellet chips, and discarded green powder coming from dosing or pelletizing that could possibly contain some debris or lost pellets collected on the glovebox floor.

This material is mixed with other discarded pellets coming from the pellet process area, crushed, and milled again to become recyclable scrap powder.

The accurate plutonium content is then determined by sampling in the Powder Auxiliary Unit.

The major equipment associated with this unit is as follows (Figure 11.2-12):

- Connection module
- Jar elevator with tilter
- Conveyor system
- Dosing station

[1] The term *scrap* in this context refers to recycled material and not to the term as defined in 10 CFR Part 74. See CAR Chapter 13 for additional information.

- Discarded pellet line with stainless steel box tilter, vibrating conveyors, bowl feeder, crusher, and loading tube
- Stainless steel box elevator
- Stainless steel box scale
- Turning arm
- Two linear conveyors
- Pot scale for manual weighing
- Bar code reader
- TV cameras
- Dust collection network
- Maintenance crane.
- Glovebox incorporating the structure to support the elements.

The Scrap Processing Unit prepares the recyclable products in two lines, both loading the same dosing station. One line handles discarded pellets, while the second line handles discarded powders. Both lines identify and weigh all incoming/outgoing containers from/to the Jar Storage and Handling Unit and the Scrap Pellet Storage Unit. The discarded pellets are crushed and sent to the Scrap Milling Unit for micronization.

This powder mix is sent to the Scrap Milling Unit for homogenization and then sampled and returned to the Scrap Processing Unit as discarded and recyclable scrap powder with a known plutonium content.

During normal operation, the process is semi-automatic. An operator supervises the fully automated parts of the process (container transfer) from the control room. Another operator performs the manual operations, working at the handling table or inspecting the pellets spread in the channels. This operator uses pushbuttons to start and stop process sequences. A telephone network connects the two operators.

The following manual operations take place during normal production:

- Transferring pots between the round basket on the elevator upper level and linear transfer conveyors to the working table
- Inspecting the contents of the stainless steel box dumped onto the wide vibrating channel and verifying that the box is empty
- Handling the sieve under the pot tilter wheel to empty it into the inspection channel
- Handling pots from the stainless steel box or pot conveyor on the working table (e.g., handling, pot opening, weighing, identification, pouring with tilter wheel)
- Handling pots between the round basket and the dust collection system
- Weighing and identifying those pots
- Connecting the pot to the dust collector
- Calibrating scales with standard weights.

The normal operations are organized in batches according to a predefined program (i.e., preparation of a crushed pellet jar or a powder jar). The batch preparation process involves identifying the pots to be mixed or the stainless steel boxes with discarded pellets to be crushed according to the weights and characteristics of the products available as well as the target enrichment and target isotopic composition of the pellets in production.

The Scrap Processing Unit is interconnected with the Jar Storage and Handling Unit, the Scrap Pellet Storage Unit, the Pellet Handling unit, and the MMIS system with its embedded MC&A application. The unit has its own monitor in the control room and a local control cabinet on the unit work floor.

11.2.2.12 Scrap Milling Unit

The Scrap Milling Unit is identical to the Primary Blend Ball Milling Unit and is intended to mill scrap. Both units are able to process both products in case the other is unavailable.

11.2.2.13 Powder Auxiliary Unit

The function of the Powder Auxiliary Unit is to prepare powder samples for the laboratory. The unit also performs powder density measurements, granulometric evaluations, and flowability characterizations mainly during the facility startup phase. The unit weighs and identifies each processed pot and vial. The unit is capable of calling any powder container for weighing and identification.

Secondary functions performed by the Powder Auxiliary Unit include the following:

- Removal and packaging of used mill balls and preparation of new mill ball loads
- Inspection, maintenance, and cleaning of powder containers
- Collection and recycling of powder generated in container cleaning and maintenance operations.

- Pre-loading of dust pot with UO_2 to be sent to the Primary Dosing Unit for dust collection system emptying

The major equipment associated with this unit is as follows (Figure 11.2-13):

- Connection module
- Jar and round basket elevator
- Conveyor system
- Worktable with test equipment and scales
- Bar code reader
- Pneumatic transfer system connection to the laboratory
- Jar handling and maintenance station with a bag port
- Electric crane
- Storage position for one jar and one tooling or transfer container
- Worktable
- Upper handling crane
- Vacuum extractor with decloggable filters and powder receiver
- Glovebox incorporating the structure to support the elements.

During normal operation, the process is mainly manual with semi-automatic sequences. An operator supervises the fully automated transfer of containers between the Jar Storage and Handling Unit and the Powder Auxiliary Unit from the control room. Another operator performs all the manual operations, working at the various tables, using pushbuttons to start and stop process sequences. A telephone network connects the two operators.

The Powder Auxiliary Unit is interconnected with the Jar Storage and Handling Unit and the MMIS system with its embedded MC&A application. It has its own monitor in the control room, as well as a local control cabinet on the unit work floor. It is also interconnected to a pneumatic transfer device to send samples to the laboratory. This interconnection is by manual transfer of vials between the Powder Auxiliary Unit and the Pneumatic Transfer Station.

11.2.2.14 Jar Storage and Handling Unit

The purpose of the Jar Storage and Handling Unit is to store containers with empty and full jars holding powders at various stages of the production process. It also stores round baskets with powder pots, as well as special containers (e.g., maintenance containers, calibration weights).

The unit also transfers containers between all the powder units and provides a buffer function. The unit is installed in a closed area isolated from production units.

The Jar Storage and Handling Unit is located in a long glovebox with approximately 58 storage positions for J60 and J80 jars. Jars are stored with their casks that are also radiation shields. In addition, temporary positions for storage jars exist on the transfer conveyors. The storage positions are located on either side of a runway served by a trolley. A spare trolley is available.

The trolley also serves conveyors feeding production stations via a connection module. In this module, jars are identified and weighed when they leave or enter a production station. This weighing operation is independent of those needed for dosing.

In short, this unit provides for identification and weighing of all incoming/outgoing containers from/to a production unit in connection modules (one for each unit), and reception, storage, transfer, and delivery of containers to production units.

The main components of the Jar Storage and Handling Unit are as follows (Figures 11.2-14 and 11.2-15):

- Eight connection modules with their jar scale, associated lifter, and jar lid handling
- Modular glovebox assembly containing the system
- Steel plates isolating a production unit from a storage unit
- Conveyor systems
- Central railroad
- Two trolleys with a locking device and a driving system
- Two trolley garages.

During normal operation, the process is fully automatic and supervised by an operator from the control room.

The operations that remain manual are introduction and removal of heavy mechanical components for maintenance, periodic cleaning with a vacuum cleaner, and other system maintenance.

This unit services the Primary Dosing Unit, the Final Dosing Unit, two ball mills, two Homogenization and Pelletizing Units, the Scrap Processing Unit, and the Powder Auxiliary Unit.

The Jar Storage and Handling Unit is interconnected with each Powder Area production unit and the MMIS system with its embedded MC&A application.

11.2.2.15 Green Pellet Storage Unit

The function of the Green Pellet Storage Unit is to provide the storage and transfer capacities needed to reach the specified MFFF throughput.

The Green Pellet Storage Unit is located in a glovebox installed in a specific room. It receives green pellet boats from the pelletizing units and empty boats from the grinders via the Sintered Pellet Storage Unit.

This unit includes the following main components (Figure 11.2-16):

- Glovebox with two parts (a storage part and a maintenance part)
- Storage rack (approximately 449 storage positions) with a stainless steel-lined neutron absorber layer between each rack column, and a perforated tray under each compartment

- Three-directional stacker
- Ventilation system
- Three pellet handling system connections
- Maintenance winch.

In normal operation, the process is fully automatic and supervised by an operator from the control room. All the equipment is controlled by a PLC in connection with the PLCs of surrounding production units. The manual operations are limited to repair or maintenance operations.

The Green Pellet Storage Unit interfaces with the two pelletizing units on one side, the two sintering furnaces on the other side, the Sintered Pellet Storage Unit, and the MMIS system with its embedded MC&A application.

11.2.2.16 Sintering Units

This section provides a design description of the MFFF pellet sintering furnaces. Sintering furnace design basis are provided in Sections 11.4.11 and 8.7.

The functions of the pellet sintering units are as follows:

- Receive incoming boats (i.e., Mo-boats) loaded with green pellets
- Temporarily store the boats
- Place the boats on shoes
- Introduce the boats into a pre-sintering zone
- Move a train of boats through the furnace
- Sinter the pellets in the furnace
- Cool the sintered pellets
- Remove the boats from the furnace
- Remove the boats from the shoes
- Perform pellet specific gravity check after sintering
- Transfer the boats to the Sintered Pellet Storage Unit.

The MP is provided with two identical Sintering Furnace Units and associated support equipment. Each furnace is divided into three heating zones: preheating, sintering and cooling. In the preheating zone, lubricant and poreformer contained in the pellet is removed. In the sintering zone, the pellets are sintered to achieve the required material properties. Pellet cooling is performed in the last furnace section prior to exiting the furnace at the furnace outlet airlock. The entire sintering process is performed under a scavenging blanket gas (mix of argon, hydrogen, and moisture).

Green pellet boats are positioned on a molybdenum shoe and then transferred to the furnace. Inlet and outlet airlocks are provided for atmospheric changes. A pusher system provides continuous motion of the boat on the shoe stack through the furnace. The last boat introduced into the furnace pushes the preceding ones. Boats are identified and weighed when they enter and leave the furnace units. After sintering, a few pellets are sampled from each boat and checked for specific gravity at an inspection station. Boats are then stored in the Sintered Pellet Storage Unit.

The sintering furnaces are not contained in glove boxes. Infrequent maintenance operations, such as a sintering module replacement, (1 m length by 1.1 m in diameter) need adequate space for the handling of each module. Due to the module's size, it is not practical for this module to be located in a glovebox. Moreover, a significant part of the cooling is performed through the natural convection in the room, which would be difficult to guarantee inside a glovebox. Note, that the pellet introduction and removal operation is performed through airlocks at both furnace ends inside glove boxes maintained under a negative pressure nitrogen atmosphere.

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Operating at a slight overpressure prevents oxygen from entering the furnace and improves heating resistor life-time.

Seal failures are not expected to occur.

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The scavenged gas leaving the furnace is cooled and filtered before being extracted via the Very High Depressurization (VHD) System. For worker protection, the outer shell and penetrations of the furnaces are also cooled by a closed water loop maintained at the desired temperature by chilled water in heat exchangers.

The Sintering Units are divided into the following gloveboxes or equipment items (Figures 11.2-17 and 11.2-18):

- Specific gravity checking glovebox
- Transfer tunnel
- Mo-boat dispatch glovebox
- Furnace inlet glovebox
- Furnace
- Furnace outlet glovebox
- Return glovebox
- Offgas treatment glovebox
- Cooling water distribution
- Sintering gas preparation and control.

The process is fully automatic and supervised by an operator from the control room.

Each Sintering Unit has only one interface with other production units. This interface is the vertical axis tunnel connecting the roof of the specific gravity checking glovebox to a pellet handling system tunnel. Through this interface, the Mo-boats are introduced and removed. At the elevator base, a scale and an identification device weigh and recognize any incoming and outgoing pellet box from the furnace unit. An interface with MMIS provides data for the MC&A application to monitor the material traffic.

The furnace gas networks have the following interfaces with the utilities:

- One for the argon supply
- One for the argon and hydrogen mixture supply with a fixed composition as prime backups
- One for the argon and hydrogen mixture supply with an adjustable composition
- One for the nitrogen supply (lock scavenging, valve actuating)
- One for the demineralized water supply to feed the moisture control system
- One for water discharge for the same system
- Connections with the offgas extraction system.

The furnace gas networks feature several controls to monitor and regulate the furnace internal pressure, oxygen content, and temperature.

Moisture is added to the process gas by a humidifier prior to entering the furnace. The moisture content of the gas is required to satisfy sintering process requirements. High humidifier water level isolates the humidifier water feed line to prevent water carryover to the furnace and subsequent over pressure due to rapid steam generation.

In the event that hydrogen is detected in the furnace room, the gas supply is automatically shifted to pure Ar.

Furnace cooling is provided by cooling water coils located on the outside of the furnace shell. The furnace cooling network interfaces with the following utilities:

- Demineralized water supply (primary loop filling)
- Chilled water supply (one inlet and one outlet)
- Dumped water supply (back-up cooling)
- Wastewater collection system.

Controls on the furnace outer shell and in the cooling network keep the furnace shell and seal temperatures within limits. To increase the furnace availability, back-up cooling water fed by gravity supplies water to the furnace cooling loops. Heating and cooling electrical power are supplied by both normal and standby diesel generator power systems. The furnace design tolerates the complete loss of cooling with power shutdown. Upon the complete loss of furnace cooling water, the shutdown of furnace resistance heating ensures seal temperatures remain less than maximum allowable temperature. The furnace shell/cooling water coil configuration prevents the intrusion of cooling water into the furnace and the associated hazards (i.e., criticality and furnace overpressure due to steam formation).

Furnace over-heating is prevented with the following set of controls. Each heating zone (3 pre-heating and 8 sintering zones) is controlled by a PID controller driven by one thermocouple. Each zone is monitored by another thermocouple placed aside of the first in the same thermowell. Each flange or vessel part containing a seal is monitored by surface thermoswitches. The flow in the main cooling loop is monitored by three flowmeters.

If two of three flowmeters show a low cooling water flow, heating power is shutdown on all heating elements and the back-up cooling (lost water) is initiated. If over-heating is detected by a monitoring thermocouple, the power to the related zone is shut-down.

If a thermoswitch in the neighborhood of a seal is activated by a high temperature, the heating power of the related zones is shut-down. The surface thermoswitch is activated at approximately

60°C, while the seals are designed for peak temperature of 316°C. Actual setpoints will be determined during final design.

11.2.2.17 Sintered Pellet Storage Unit

The function of the Sintered Pellet Storage Unit is to provide the storage and transfer capacities needed to reach the specified MFFF throughput.

The Sintered Pellet Storage Unit is installed between the sintering furnaces and the Grinding Units. The Sintered Pellet Storage Unit has the same design as the Green Pellet Storage Unit and also features approximately 449 storage positions. Each position is able to receive either a Mo-boat or a stainless steel box.

The Sintered Pellet Storage Unit interfaces with the two Sintering Units, the Green Pellet Storage Unit, the two Grinding Units, the Pellet Repackaging Unit, the Ground and Sorted Pellet Storage Unit, and the Scrap Pellet Storage Unit. An interface with the MMIS provides data to the MC&A application.

11.2.2.18 Grinding Units

The functions of the Grinding Units are as follows:

- Grind sintered pellets to the diameter specified for finished pellets

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- Reject out-of-tolerance pellets
- Load accepted pellets onto grooved trays stacked in baskets
- Transfer the pellets to the Ground and Sorted Pellet Storage Unit
- Collect scraps produced in the units

[ ]

The two identical Grinding Units grind the sintered pellets by dry process. The grinding process is performed in four dedicated gloveboxes with connections to the Sintered Pellet Storage Unit glovebox and the Ground and Sorted Pellet Storage Unit glovebox. Sintered pellets are transferred in boats from the Sintered Pellet Storage Unit. The boat is weighed, identified, and then tilted. The pellets fall onto a conveyor. The pellets are laid out in line and then directed to the grinding wheels. Grinding dust is removed through a dust removal loop fitted with self-cleaning filters. The dust is then collected in cans, which are weighed and transferred in stainless steel boxes to the Scrap Pellet Storage Unit for further processing in the Scrap Processing Unit. After the dust is removed from the pellets, the pellets are checked for diameter and loaded into a tray basket. When full, the tray basket is identified, weighed, and transferred to the Ground and Sorted Pellet Storage Unit.

Each Grinding Unit includes equipment installed in four separate gloveboxes connected together by tunnels. The four gloveboxes are as follows (Figures 11.2-19 through 11.2-21):

- Supply glovebox
- Grinding glovebox
- Basket filling glovebox.

The Grindings Unit interfaces with the Sintered Pellet Storage, the Ground & Sorted Pellet Storage Unit, the Scrap Pellet Storage and the MMIS system with its embedded MC&A application.

11.2.2.19 Ground and Sorted Pellet Storage Unit

The function of the Ground and Sorted Pellet Storage Unit is to provide buffer storage and transfer capacities.

The Ground and Sorted Pellet Storage Unit serves the Grinding Units, the Quality Control and Manual Sorting Units, the Rod Cladding and Decontamination Units, and the Rod Decladding Unit.

The Ground and Sorted Pellet Storage Unit has a similar design as Green Pellet Storage Unit but features two areas. In the first area, the storage compartment is sized to match the size of a tray basket. In the second area (approximately 12 containers), each storage compartment can accommodate a stainless steel box of scrap pellets or two dust pots. The maximum capacity of the whole storage is approximately 201 containers.

The Ground and Sorted Pellet Storage Unit interfaces with the served units and with the MC&A application embedded in the MMIS system.

11.2.2.20 Pellet Inspection and Sorting Units

The functions of the Pellet Inspection and Sorting Units are as follows:

- Receive and unload tray baskets filled with ground pellets
- Inspect the peripheral surface and measure the diameter of each pellet
- Place accepted pellets into a tray
- Place rejected pellets into a stainless steel box
- Dubious pellets are inspected by an operator
- Collect samples of accepted pellets for further quality inspections.

Two identical units are installed. In each unit, the sorting process takes place in two gloveboxes: the sorting glovebox and the basket loading glovebox (Figures 11.2-22 and 11.2-23). Containers from the Ground and Sorted Pellet Storage Unit are identified, weighed, and then unloaded. The pellets are laid out in line and automatically inspected and sorted. The inspection leads to three types of pellets: good or accepted, rejected, and suspect. The good pellets are placed in tray baskets and returned to storage. The rejected pellets are loaded into stainless steel boxes and transferred to the Scrap Pellet Storage Unit. Suspect pellets, pellets which were neither accepted nor rejected from automatic inspecting and sorting, are transferred to a manual sorting table to be inspected by an operator.

In addition to the automatic inspection and sorting, the good pellets are sampled throughout the batch and stored in a tray basket for transfer to the Quality Control Unit.

Except for the visual sorting of suspect pellets, the process is fully automated and supervised by an operator from the control room. The whole system is driven by a PLC in connection with the PLCs of surrounding equipment.

Each Pellet Inspection and Sorting Unit has two connections with the pellet handling system: one connection with the sorting glovebox and the other connection with the basket loading glovebox. The units also interface the MC&A application embedded in the MMIS system.

11.2.2.21 Quality Control and Manual Sorting Units

The functions of the Quality Control and Manual Sorting Units are to perform additional visual and dimensional inspections on a sample of sorted pellets according to the pellet specifications and to take samples to be directed to the laboratory for further inspections. The results of those inspections establish the status of the whole pellet batch: either accepted or rejected. [ ] This additional inspection on each batch includes the following:

- Visual checking and manual measurement by an operator (dishing inspection, roughness measurement and chamfer measurement)
- Automatic diameter measurement
- Automatic length measurement
- Automatic perpendicularity measurement
- Automatic weight measurement.

Equipment used in the Quality Control and Manual Sorting Units is as follows: (Figures 11.2-24 and 11.2-25):

- Scale
- Manual measurement devices (dishing, roughness and chamfer)
- ATI machine (for diameter, length, and perpendicularity measurements)
- Laser micrometer
- A robot which carries out automatic measurement (pellet weigh, pellet length, perpendicularity and diameter)

The quality control and manual sorting process takes place in two gloveboxes (the handling and re-sorting glovebox and the quality control glovebox). All incoming and outgoing containers are identified and weighed. The samples of sorted pellets come from the Ground and Sorted Pellet Storage Unit, and the samples are returned to that unit after inspection. Some sampled pellets are pneumatically transferred to the laboratory for physical and chemical analyses.

The pneumatic transfer system is installed in a separate glovebox and is isolated from the handling and re-sorting glovebox by a sliding door. This separate glovebox prevents ventilation disturbances in the handling and re-sorting glovebox in case of a pneumatic transfer system malfunction. Pneumatic devices (e.g., pumps, regulators) are installed outside the glovebox.

Some sample pellets from each batch are stored in the archives. Sampling is performed in the handling and re-sorting glovebox from accepted pellets. The pellets are stored in small stainless steel bottles, which are loaded into a stainless steel box. Full boxes are stored in the Ground and Sorted Pellet Storage Unit.

In the Handling and Re-sorting glove box, the operator inspects visually pellets and poured into pots rejected pellets.

In the Quality Control glove box, an operator fills the tray with pellets and sends it to the pellet handling robot. The robot picks the pellets up from the tray, handles them between the automatic control stations, and puts them back at the same place on the tray. The operator can re-check pellets rejected by the robot, using manual measurement devices.

In normal operation, the process is automated and supervised by an operator from the control room. Manual workstations are also installed in the unit where operations are carried out manually. Local control desks perform the connection with the PLC.

The Quality Control and Manual Sorting Units interface with the Ground and Sorted Pellet Storage Unit, the Pellet Inspection and Sorting Units through the Pellet Handling Unit, the laboratory through the pneumatic transfer system, and the MMIS system with its embedded MC&A application.

11.2.2.22 Scrap Box Loading Unit

The main process function of the Scrap Box Loading Unit (Figure 11.2-26) is to repackage scrap pellets contained in either Mo-boats or partially filled stainless steel boxes into completely full stainless steel boxes. The secondary process functions are handling, weighing, and identifying the incoming and outgoing containers. All incoming and outgoing containers are identified and weighed.

The container handling equipment is as follows:

- Lift handling Mo-boats and stainless steel boxes
- Container identification and weighing station
- Upper horizontal conveyor.

The stainless steel box loading equipment is as follows:

- Mo-boat and stainless steel box
- Belt conveyor and chute

- Stainless steel box loading lifter equipped with a table
- Scale.

In normal operation, the Scrap Box Loading Unit can be fully automated and supervised by an operator from the control room.

The Scrap Box Loading Unit interfaces with the Sintered Pellet Storage Unit, the Scrap Pellet Storage Unit and the MMIS system with its embedded MC&A application.

11.2.2.23 Pellet Repackaging Unit

In this unit, all pellet containers are maintained and cleaned and all incoming and outgoing containers are weighed and identified. This unit also provides the ability for safeguard inspectors to inspect the pellet containers.

In normal operation, the containers are introduced, removed, identified, and weighed automatically. An operator in the control room supervises operations. Basket emptying is operated in semi-automatic mode under the control of a nearby operator. An operator starts each semi-automatic cycle and performs the required manual operations.

Pellets from containers other than baskets can be repackaged manually at the maintenance station. Container maintenance, inspection, and cleaning are performed manually at the maintenance station. Interlocks are provided to prevent collisions between automatically and manually operated equipment.

The Pellet Repackaging Unit interfaces with the Pellet Handling Unit. The Pellet Repackaging Unit lift receives the incoming containers and places the outgoing containers on the trolley of the Pellet Handling Unit. The connection is located in the glovebox roof of the Pellet Repackaging Unit.

11.2.2.24 Scrap Pellet Storage Unit

The function of the Scrap Pellet Storage Unit is to provide the buffer storage and transfer capacities. This storage unit has the same design as the Green Pellet Storage Unit and is used to store up to approximately 443 stainless steel boxes.

The Scrap Pellet Storage Unit interfaces with the Scrap Box Loading Unit, the two Grinding Units, the Pellet Repackaging Unit, the Sintered Pellet Storage Unit, the Ground and Sorted Pellet Storage Unit, the Scrap Processing Unit, the filter maintenance glovebox, and the MMIS with its embedded MC&A application.

11.2.2.25 Pellet Handling Unit

The function of the Pellet Handling Unit is to connect the various storage and production units with a transfer system capable of moving all types of pellet containers through tunnel-like gloveboxes interconnected by bellows.

The pellet handling system has the following characteristics (Figure 11.2-28). Each trolley can be loaded with one container placed on each of four corners of the carriage base plate. Each transfer section contains only one trolley at a time. The containers are placed onto and picked up from the trolley by means of a unit lift or dedicated lifters. The pellet handling system requires the following accessories: elevators, lifters, rotating tables, and positioning systems.

In normal operation, the process is fully automatic and supervised by an operator from the control room. Manual operations are limited to repair or maintenance operations.

Trolley tracks are provided in various areas, each under the control of a storage PLC in connection with the PLCs of surrounding equipment. Interfaces between the areas take place at an unit entrance.

11.2.2.26 Rod Cladding and Decontamination Units

The function of the Rod Cladding and Decontamination Units is to manufacture and decontaminate MOX fuel rods by filling cladding tubes with ground and sorted pellets. The lower plugs of the tubes are pre-welded. The pellets are inserted into the cladding tubes. After insertion of the spring, the upper plug is welded under helium. The rod is then pressurized with helium, and the seal is welded. The rods are then decontaminated and checked for any residual contamination. Subsequently, the rods are removed from the glovebox and loaded onto rod trays. The general arrangement is shown on Figure 11.2-29.

The Rod Cladding and Decontamination Unit includes a main rod handling glovebox (Figure 11.2-30) to which five processing stations are connected.

The first two stations are comprised of similar rod filling stations. Both include four gloveboxes performing the following functions: stack preparation, cladding tube filling, tube end cleaning, and spring and plug insertion (Figure 11.2-31 and 32).

The Rod Cladding and Decontamination Unit is fitted with an additional station (fifth) for repairing the rod upper plug in case of a welding nonconformity (see Figure 11.2-35). Inside the unit the rod is cut below the plug. Then the spring is removed and a new spring and plug are installed. The rod subsequently follows the normal process steps: welding, pressurization, and decontamination.

The Introduction lines are two identical structures that receive empty tubes or rods by manual transfer from a trolley and feed them individually through an introduction port into the handling glovebox.

Empty tubes are normally supplied via the first Introduction Line (see Figure 11.2-36).

Rods requiring repair are supplied via the dedicated Introduction Line.

After loading a rod tray with rods, full trays are placed into the Rod Storage Unit. Weld samples of short non-loaded rods from the two units are sent to the laboratory for metallographic and corrosion testing.

The Rod Cladding and Decontamination Unit interfaces with the pellet handling system, the Rod Tray Loading Unit, and the MMIS system with its embedded MC&A application.

11.2.2.27 Rod Tray Loading Unit

The Rod Tray Loading Unit receives empty trays from the Rod Storage and loads rods transferred from the Decontamination Line of the Cladding And Decontamination Unit on these trays. Upon completion, trays are sent back to the Rod Storage. The unit also receives rejected rods from the Rod Storage and discharges the rods to a loading position for manual transfer to a trolley for further processing.

The Rod Tray Loading Unit contains the following equipment:

- Two traveling conveyors
- One loading station
- One removal track.

In normal operation, the Rod Tray Loading Unit is automated and supervised by an operator from the control room. However, a few manual operations are necessary during normal operation.

The Rod Tray Loading Unit interfaces with the Rod Storage Unit through a tray lift.

11.2.2.28 Rod Tray Handling Unit and Rod Storage Unit

The functions of the Rod Tray Handling Unit and Rod Storage Unit are to provide rod tray storage in a ventilated compartment, and to allow for rod tray transfer via a lift between the cladding room situated on level 2 and level 1 of the building.

The Rod Tray Handling Unit and Rod Storage Unit are used by the Rod Cladding and Decontamination Unit, the Helium Leak Test Unit, the X-Ray Inspection Units, the Rod Scanning Unit, the Rod Inspection and Sorting Unit, and the assembly mockup loading station. A tray stacker serves the storage modules on one side and the production and inspections units on the other side.

The following equipment is installed in the Rod Tray Handling Unit and Rod Storage Unit (Figures 11.2-37 and 11.2-38):

- Lift interconnecting building levels 1 and 2
- Tray stacker system that consists of the following:

- Motor-driven trolley riding on two horizontal rails extending over the entire length of the storage (X-axis), and supporting a drive motor used for vertical movement of the tray reception table
- Motor-driven tray reception table moving up and down (Z-axis) along a frame secured to the trolley. The table is free to move sideways (Y-axis) to ensure docking to the storage modules and workstations. The rod tray is moved by a motor-driven roller system. A mechanism is provided to detect any overlapping rods on the tray before it is inserted into the storage.

- Series of eight concrete storage compartments, each of which contains three columns of tray storage racks. Each layer of trays within each compartment is separated by a moderator screen. The trays are secured to the storage rack by a latch actuated by a drive system mounted on the stacker table. The rods are maintained on the trays by a restraining bar. The storage compartments are ventilated at the top through orifices.
- An additional concrete module is maintained empty as reserve storage.

In normal operation, the process in the Rod Tray Handling Unit and Rod Storage Unit is fully automated and supervised by an operator from the control room.

The Rod Tray Handling Unit and Rod Storage Unit interfaces with the Rod Cladding and Decontamination Unit, Rod Scanning Unit, Rod Inspection and Sorting Unit, Helium Leak Test Unit, X-Ray Inspection Units (two units), Assembly Mockup Loading Unit and the MMIS system with its embedded MC&A application.

11.2.2.29 Helium Leak Test Unit

The function of the Helium Leak Test Unit is to check the leak tightness of fuel rods pressurized with helium. A single rod tray is received, identified, and unloaded in the Helium Leak Test Unit, introduced into the vacuum chamber, and tested. The rods are reloaded onto the tray and transferred again to storage. If a leak is detected, the defective rods are identified by dichotomy.

The Helium Leak Test Unit has the following components (Figure 11.2-39):

- Receiving table
- Feeding device
- Vacuum chamber with a mass spectrometer.

In normal operation, the process in the Helium Leak Test Unit is fully automated and supervised by an operator from the X-Ray Inspection Unit control room.

The Helium Leak Test Unit interfaces with the Rod Storage Unit via the stacker of the rod handling glovebox.

11.2.2.30 X-Ray Inspection Units

The function of the X-Ray Inspection Units (Figure 11.2-40) is to perform an X-ray inspection of fuel rods. There are two X-ray inspection units: one is fully automated with radioscopic image analysis, and the other with conventional film handling and interpretation.

The first unit is used to successively radiograph the upper part of the rods to check for the presence of springs and to check for the quality of both the plug weld and the seal weld. After receipt and identification of the rods, each rod is inserted one after the other into this X-ray inspection device. Three shots at 120° of rod rotation are performed, and radioscopic images are automatically analyzed by software. The resulting status is attached to each tested rod. Once the rods have been tested, the rod tray is returned to the Rod Storage Unit.

The second unit uses X-ray film to calibrate the first unit. In addition, in case of doubt regarding the presence of gap in pellet stack or pellet integrity or at the request of the Production Manager, the pellet stack of individual rods in the tray can be inspected.

The X-Ray Inspection Units are fully automated, except for film handling and evaluation of the films of the second unit, which are examined by a specially trained operator.

The X-Ray Inspection Unit interfaces with the Rod Storage Unit.

11.2.2.31 Rod Scanning Unit

The function of the Rod Scanning Unit is to check for alpha contamination on the fuel rods, to inspect the pellet stacking inside the fuel rods, and to assess pellet-to-pellet variations in the rods. After receipt and identification of a rod tray, each rod is sequentially inspected. Each rod passes successively through three measuring cells:

- Gamma transmission cell for inspecting internal pellet stacking
- Alpha counting cell for performing an alpha contamination check
- Active gamma scanning cell for assessing plutonium content.

The status of each rod is assigned to each rod. Once the rods have been tested, the tray is returned to the Rod Storage Unit.

Rods are checked on a sample basis for removable alpha contamination.

The major equipment associated with the Rod Scanning Unit is as follows (Figure 11.2-41):

- Tray handling system comprised of a receiving table with bar code reader, a traveling conveyor, a rod feeding assembly, and an exit table
- Inspection track comprised of the following:
    - Motorized rollers
    - Bar code reader
    - Two gamma detectors in front of two americium sources
    - Four alpha detectors

- Californium neutron source with a set of four gamma detectors
- Sweeping arm with a smear block.

The rod scanning process is fully automated. The Rod Scanning Unit interfaces with the Rod Storage Unit through the stacker.

11.2.2.32 Rod Inspection and Sorting Unit

The function of the Rod Inspection and Sorting Unit is to perform dimensional and visual inspection of the rods and subsequently to sort the rods according to their status assigned during all the previous tests. These inspections are carried out at the end of the inspection cycle, prior to assembly fabrication. The unit also sorts the inspected fuel rods into four categories: accepted rods, rods to be repaired in case of a weld defect, rods to be decladded, and rods to be reinspected (X-Ray Inspection Units or Rod Scanning Unit).

Each rod category is loaded onto specific trays, which are transferred back to the Rod Storage Unit. During rod inspection, the unit automatically measures the rod length, rod straightness, and upper plug alignment with the tube.

An operator visually inspects all the rods from the same tray, and the rods are rotated. The operator inspects for rod cleanliness, general appearance, and the upper plug weld diameter. The operator records the number and the positions of each defect in the defective rods.

Sorting can only be performed upon completion of all other inspections (helium leak test, X-ray inspection, rod scanning, dimensional inspection, and visual inspection).

The Rod Inspection and Sorting Unit has three stations (Figure 11.2-42): dimensional inspection station, visual inspection station, and sorting equipment.

In normal operation, the process is fully automated except for visual inspection and weld diameter measurement.

The sorting equipment interfaces with the Rod Storage Unit through the stacker.

11.2.2.33 Rod Decladding Unit

The function of the Rod Decladding Unit is to cut open rejected rods to recover the pellets. The tube cannot be reused and therefore is cut into segments and packaged as waste. Normally, the pellets are not used again but are sent to the Scrap Processing Unit. However, if the pellets are to be used again, they are placed into a basket to again be sorted.

As shown in Figure 11.2-43, the Rod Decladding Unit is equipped with the following items:

- Tilting table with a vibrator
- Glovebox containing tools, including a plug-cutting tool, manual workstation, scale, motorized lift, bar code reader, and camera.

Operations in the Rod Decladding Unit are carried out manually. The Rod Decladding Unit interfaces with the pellet handling system.

11.2.2.34 Assembly Mockup Loading Unit

The function of the Assembly Mockup Loading Unit is to place the rod bundle in the correct configuration before inserting it into the assembly structure. The major equipment associated with this unit are (Figure 11.2-44) a subassembly feeding track and a subassembly mockup loading.

In normal operation, the mockup loading process is fully automated and supervised by an operator in the control room. Initially, the mockup is empty at the emptying station. No rod trays or rods are present on the feeding track.

A rod tray is transferred from its storage position to the reception device on the feeding track. It is then brought to the rod insertion equipment by the lateral conveyor. The tray bar code is read before the transfer. When the rods necessary for an assembly are in the mockup, the tray is conveyed up to the removal device and is then picked up by the stacker.

Each rod is lifted from its position and then inserted into the rod mockup. A bar code reading is made before the rod is fully inserted into the mockup. A check is made by comparing the code with the tray code and the requested enrichment. If there is a reading problem, the rod is rotated a quarter of a turn and a new reading is made. The position of the rod in the mockup is checked by means of the mapping system.

When the mockup is full, the sash door closes, the mapping system is disconnected from the mockup, and the mockup is transferred to the emptying station. The mockup stops at the emptying station.

The mockup is then picked up by the rotation equipment which raises, rotates 180° and lowers the mockup onto the mockup conveyor, such that rod upper end caps face the pulling fixture, allowing proper rod gripping.

The Assembly Mockup Loading Unit interfaces with the Assembly Mounting Unit, the Rod Tray Loading Unit and the MMIS system with its embedded MC&A application.

11.2.2.35 Assembly Mounting Unit

The function of the Assembly Mounting Unit is to insert rods staged in the mockup into fuel assembly structures to form MOX fuel assemblies. The assembly structure is mounted on the pulling fixture with the assembly mockup positioned in front of the structure.

The rods are pulled into the structure, layer by layer using tie-rods. Top and bottom fittings of the assembly are then mounted. The assembly is vertically tilted and removed from the pulling fixture to be transferred to the assembly inspection area.

The Assembly Mounting Unit performs the following main functions:

- Positions the assembly structure
- Pulls the fuel rods
- Retains the assembly ends
- Crimps the guiding tubes
- Tilts the assembly.

The major equipment associated with this unit is presented in Figure 11.2-45.

In normal operation, most of the process is automated and supervised by an operator from the control room, but a few manual operations are necessary. Other parts of the process are partially automated in short cycles under the control of the operator.

The assembly mounting process is initiated with the upending fixture in the horizontal position and the pulling fixture in the idle position. The upending fixture is then fitted with a rotating supporting structure in order to allow access to the grids. The operator manually performs the setup operations (grids setting, dummy guide tube mounting, settling) and the grids are fitted with keys which allow to make free the passage through the grids for the rods.

Rods located in the mockup are inserted using a pulling fixture and tie rods. The rods are pulled by successive layers through the structure by means of tie rods. Before entering the assembly structure, the tie rods pass through a cap magazine located at the end of the upending fixture and are provided with caps. These caps protect the tie rod grips as they pass through the structure. The caps are removed after entering the structure and before the rods are pulled. Forces exerted on each passage through the grid are monitored. In the event of structure blocking, the tie rods are automatically disengaged.

After pulling of all fuel rods, the grid keys are manually removed. Then the assembly ends are put in place and the assembly guide tubes are crimped onto the bottom end. The assembly is tilted to the vertical position by the upending fixture after removal of the cap magazine and cap removal system and after lateral movement of the pulling fixture. Tilting allows installation of the gripper and transfer of the terminated assembly towards the cleaning and inspection stations.

The Assembly Mounting Unit is also capable of removing a single fuel rod or an entire layer of fuel rods from the assembly structure, if required.

The Assembly Mounting Unit interfaces with the Assembly Mockup Loading Unit and the Assembly Handling and Storage Unit. It also interfaces with the MC&A application embedded in the MMIS system as all the other units.

11.2.2.36 Assembly Dry Cleaning Unit

The function of the Assembly Dry Cleaning Unit is to remove chips produced during fuel rod pulling by blowing air within a cylindrical stainless steel pit.

The major equipment associated with this unit is as follows (Figure 11.2-46):

- Cylindrical stainless steel pit or blowing pit

- Blowing pit soundproofed top cover
- Fuel assembly lateral guide device
- Moveable nozzle pipes for blowing air onto fuel assemblies
- Exhaust fan
- Rotating coil filter for trapping zircaloy chips
- Station control desk in the process room.

In normal operation, the process is automated and supervised by an operator from the control room. Manual workstations are also installed in the unit where operations are carried out manually.

To initiate the process, a fuel assembly is transferred above the blowing pit. The assembly type to be cleaned is identified and selected by the operator, and the blowing cycle is started. The lateral fuel assembly guides are set to a pre-adjusted cross-section, the soundproof covers are closed, and the air exhauster is started. The blowing nozzles, along with their backward and forward movement, are started.

The operator lowers the assembly with the hoist until the whole assembly length is cleaned and then slowly raises the assembly to the cycle end. The nozzles and fan automatically stop, the guiding device retracts, and the covers open. The operator then transfers the assembly to the next process step.

The Assembly Dry Cleaning Unit interfaces with the Assembly Mounting Unit, the Assembly Dimensional Inspection Unit, and the Assembly Final Inspection Unit.

11.2.2.37 Assembly Dimensional Inspection Unit and Assembly Final Inspection Unit

Following fuel assembly cleaning, the assembly is inspected at the Assembly Dimensional Inspection Unit and the Assembly Final Inspection Unit.

The Assembly Dimensional Inspection Unit (Figure 11.2-47) performs the following checks:

- Assembly length
- Assembly verticality
- Envelope between the grids and the assembly ends
- Distance between individual rods.

Geometry is measured by sensors mounted on a support running along a straight tower around the assembly. Sensors are calibrated before each measurement.

The Assembly Final Inspection Unit (Figure 11.2-48) performs the following checks:

- Visual inspection of assembly faces for detection of foreign objects between the fuel rods
- Foreign objects in guide tubes
- Control cluster insertion test

- Plugging device insertion test
- Assembly plutonium content.

Visual inspection is performed either by a TV system with wide angle and close-up view lens set or visual observation using a periscope (for radiation protection) with magnifying possibilities. Various lighting systems can be selected to enhance observed defects. Each face is successively inspected along the whole assembly length using a hoist and guiding systems on a 4-quadrant turntable.

The control cluster insertion test is performed using a hoist, a load cell and a dummy cluster as a gauge; insertion and extraction forces are monitored. The plugging device insertion test is performed manually using another gauge.

If required, a burnable poison rod assembly is inserted into the assembly at this station, prior to retrieval and transfer to storage.

A reserve pit is also provided for the temporary storage of an assembly. This storage space would be used in the event of failed inspection or overnight storage for an assembly inspection to be completed the next day.

11.2.2.38 Assembly Handling and Storage Unit

The main functions of the Assembly Handling and Storage Unit are as follows (Figure 11.2-49):

- Picking up and handling assemblies between the various workstations
- Storing assemblies
- Positioning and retrieving assemblies.

In the Assembly Handling and Storage Unit, the assemblies are handled vertically using a gripper suspended to either a monorail hoist trolley or by a traveling crane. This trolley serves the various inspection stations.

The lower part of the storage unit features three rows of storage positions. The assemblies are stored on either side of the rows with their gripper and with their bottom end resting on a support. The storage capacity is approximately 114 assemblies. The upper part of the storage unit is for the bridge crane.

For assembly handling, equipment in use is as follows:

- Monorails with switching devices and hoists
- Overhead crane
- Gripper and mobile gripper storage rack

For assembly storage, equipment in use is as follows:

- Set of supports for storing the assemblies
- Upper support set with locking device

- Storage entry and exit doors.

Most of the operations are manual or semi-automatic under the direct control of an operator. Only some sequences are automatic. The system is designed to provide adequate protection against collisions or improper handling. The Assembling Handling and Storage Unit interfaces with the assembly fabrication, Assembly Dimensional Inspection Unit, Assembly Final Inspection Unit, Assembly Dry Cleaning Unit, spare pit, Assembly Packaging Unit and the MMIS system with its embedded MC&A application.

11.2.2.39 Assembly Packaging Unit

The main function of the Assembly Packaging Unit (Figure 11.2-50) is to open and close casks, load and unload the casks onto/from the transport truck, and package assemblies into the casks. Assemblies are retrieved from storage and inserted into the internal rack of the shipping cask. The rack is then lowered to the horizontal position and inserted into the cask. The cask is then closed and transferred to the shipping airlock until it is loaded into the delivery truck.

Each shipping cask is able to transport three assemblies (Figure 11.2-51). It features two main components: a containment shell with associated covers to which the two end impact limiters are secured and a strongback to hold three assemblies. The assemblies are inserted into the strongback laterally while the strongback is in an upright position. The strongback is pushed into the cask in a horizontal position.

The unit's main equipment is as follows:

- Rail-mounted motorized tilting frame for uprighting the strongback and positioning it when inserting the three assemblies, featuring the following:
  - Rigid weld-fabricated frame with motor and lifting cylinder
  - Rotating table for strongback orientation
- Motorized receiving table for placing/removing the strongback into/out of the cask and repositioning it. The receiving table consists of a frame that supports the strongback on rolls.
- Trolley for transferring the cask from the assembly packaging area to the truck, with the following:
  - Lifting platform to raise the cask level with the trailer floor
  - Air pallet that transfers the cask onto the truck
  - Twin beam crane in the assembly packaging room
  - Twin beam crane in the fuel truck bay to store the casks.

All operations are manual or semi-automatic under the direct control of an operator. The Assembly Packaging Unit interfaces with the Assembly Handling and Storage Unit.

11.2.2.40 Filter Dismantling Unit

The function of this unit is to recover MOX powder from glovebox filters prior to filter disposal. MOX powder recovery is performed to maximize the amount of the incoming plutonium used in power reactor fuel. The collected powder is sieved in the unit to separate filtering media debris and loaded into dust pots. Two loaded dust pots are placed in a stainless steel box and transferred to the Scrap Pellet Storage Unit. The pots are subsequently processed in the Scrap Processing Unit. The filters are dismantled, placed in double vinyl bags and transferred from the glovebox to a waste drum.

The unit also functions in the repackaging of waste drums containing more than 65 grams of Pu and less than 300 grams of Pu.

The Filter Dismantling Unit interfaces with the Scrap Pellet Storage Unit via the Pellet Handling Unit and the Waste Storage Unit through an enclosed shelter and bag ports. The Unit interfaces with the MMIS system and its embedded MC&A application. The unit has its own monitor in a separate control room and a local control cabinet on the unit work floor.

The major equipment associated with this unit is as follows (Figure 11.2-52):

- Glove box with partitions to limit internal contamination
- Ventilated shelter enclosure for the opening and closing of waste drums
- Dust pot and stainless steel box identification and weighing equipment
- Dust pot buffer storage
- Lathe for opening filter casing
- Manual vacuum cleaner to collect powder on the filter media and casing
- Work table to permit recovery of powder before prior to opening the filter casing
- Vibrating sieve and a dust pot to remove foreign material and collect powder
- Manual handling crane
- Bag ports to introduce filters and remove filter media and casings (double-bagged)

Transfer containers (waste drums) containing used filters are transferred from the Waste Storage Unit into the Filter Dismantling Unit shelter using a special pallet trolley moving the drum within a shielded container. An operator with appropriate personal protection equipment (e.g., respirator, etc.) opens the drum, controlling possible internal contamination using a vinyl drum head cap and a detector. If the drum is free of contamination, the cap is removed and the contained packages can be transferred. If contamination is detected, a vinyl sleeve is passed over the drum and each package is sealed in a sleeve section.

The packages are then transferred to the Filter Dismantling Unit glovebox via the large bag port and associated guillotine door.

The second operator transfers the package through the strip curtain and into the dismantling zone. The operator opens the package, turns out the bags and lets the powder fall on the table. Each filter is then drummed against the table to release as much powder as possible, the powder is pushed with a wiper into the sieve.

Each filter is then dismantled using the lathe to cut the filter casing. The filtering media is cut away by scissors (with rounded tips) or by electric knife, unfolded, brushed, vacuum cleaned and stored in a dedicated bag. Cut casing edges are protected by heavy adhesive tape and stored in another dedicated bag.

When the batch is processed, each waste bag is transferred through a bag port into the shelter, sealed in a sleeve and loaded in a dedicated drum. When a drum is full, its internal vinyl bag is sealed, drum is closed, identified with its content (paper work) and moved out the shelter with the drum handling trolley, back to the Waste Storage Unit.

Powder collected in the sieve is loaded in a dust pot, weighed, identified and pots are loaded in a stainless box by pair. Transfer of the stainless steel box to/from the Scrap Pellet Storage unit is automatic under the operator request with automatic identification and weighing of the containers.

Except the stainless steel box transfer, all operations are manual and require a crew of two.

The unit glovebox is ventilated by the Very High Depressurization Exhaust system. Internal portions provided with strip curtains ensure ventilation flow within the glovebox is from the least contaminated areas to the filter dismantling area. The shelter enclosure is ventilated by the High Depressuization Exhaust system.

11.2.2.41 Maintenance and Mechanical Dismantling Unit

The Maintenance and Mechanical Dismantling Unit functions to dismantle contaminated parts removed from production units so that they may be placed into 55-gallon waste drums. Operation of this process unit is expected to be infrequent and is not a part of the normal production process. In addition to waste preparation, a provision is made to use the unit for special mechanical maintenance of contaminated equipment in the event that maintenance cannot be performed within the respective process unit. Normal maintenance will be performed within each affected unit.

The major equipment associated with this unit is as follows (Figure 11.2-53) :

- Ventilated shelter enclosure for introduction/removal of parts
- Turning davit to handle heavy parts within the shelter
- Glove box to contain the process equipment with:
  - Telescopic transfer table for parts handling through the bag port,
  - DN 700 bag port,
  - Grooved workbench,
  - Reference table for equipment adjustment and measurements,

- Handling hoist,
- Part transfer trolley,
- Tooling trolley,
- Negative pressure control for heavy parts introduction,
- Dedicated tooling.

The double-bagged component to be dismantled or maintained is manually introduced to the shelter by trolley or out-of-dimension waste trolley. An operator with appropriate personal protection equipment (e.g., respirator, etc.) utilizes the davit to remove the waste trolley cap, place slings around the component, raise it and lay it on the table. Negative pressure in the glovebox is reduced and the introduction vinyl bag is prepared on the port for introduction.

The telescopic table is extended out of the glove box into the introduction vinyl bag and the component is handled manually with the help of the davit and engaged in the transfer bag on the telescopic table. The telescopic table retracts into the glovebox with the component in the transfer vinyl bag. A second vinyl bag is placed on the bag port and first is removed the to access the component in the box. A protective cover is installed on the port and normal glovebox negative pressure is restored.

The component is placed on the workbench and maintenance or size reduction operations are carried out as applicable. If parts are cut, sharp edges are protected with sticking bands prior to packing in vinyl bags. The components are transferred out of the glovebox through a small bag port using standard bag out procedures or through the DN 700 bag port utilizing the telescopic table.

Waste components are measured for dose rate and placed in a 55gal waste drum. Paperwork with drum contents is completed and the drum is transferred to the Waste Storage Unit using a drum trolley.

This unit has no interface with other process units. The unit glovebox is ventilated by the Very High Depressurization Exhaust system. The shelter enclosure is ventilated by the High Depressuization Exhaust system.

11.2.2.42 Waste Storage Unit

The Waste Storage unit functions to store facility solid wastes prior to being transferred for waste processing. Wastes are temporarily stored in 55-gal drums at specified locations of the MFFF building in accordance with procedures that control drum content for chemical and Pu content. Full drums are transferred to the Waste Storage Unit, measured for Pu content and then placed on a pallet. The pallet is then stored in the unit before being transferred to the Waste Nuclear Counting Unit for precise drum content determination and documentation. The pallet is returned to the waste storage unit before being transferred for waste processing.

Entry to the Waste Storage unit is made through an airlock provided with nuclear counting equipment, turning jib (davit), pallet constitution area, and conveyor to the storage room (Figure 11.2-54). Entry to the storage room is through a fire door. The storage room is provided with conveyor, pallet stacker and pallet storage racks.

Full drums to be stored are transferred from the process rooms to the Waste Storage airlock using caddies manually driven in the MFFF corridors. The drum is measured passing through the nuclear counting device in the airlock, and is placed onto a pallet using the turning jib provided with a drum gripper. Pallets are available in the airlock to sort the incoming drums according to their content. The jib is operated with a local control box.

When a pallet is completed, the operator identifies the pallet and places a request to the control room for the pallet to be introduced in the storage. Upon authorization, the pallet is placed onto a conveyor connected to the storage room. A display repeats the information from the sensor detecting the presence of the pallet on the conveyor and informs the operator that the pallet is correctly positioned. The control room operator then starts the automatic storage cycle. When the storage cycle is completed, the stacker returns to its rest position.

There are two cycles depending on whether the pallet is to be sent to the Waste Nuclear Counting unit or to the shipment area for transport by road via an airlock and a forklift. In both cases, the sequence is as follows:

- Stacker moves to the pallet storage position,
- Pallet is loaded on the stacker,
- Stacker moves to the unloading position,
- Pallet is unloaded on the required conveyor (nuclear counting or shipment area).

The Waste Storage unit is interconnected with the Waste Nuclear Counting unit, the waste drum shipment area, MMIS and its MC&A application.

11.2.2.43 Waste Nuclear Counting Unit

The Waste Nuclear Counting unit functions to identify waste drums and determine drum fissile and radioactive material content. This is accomplished by the weighing and nuclear measurement of each waste drum. The measurement equipment is located in a room adjoining the Waste Storage unit, separated by a fire- door. Pallets are transferred out of the Waste Storage unit to the Waste Nuclear Counting unit for assay. A pallet may be directly sent from the material airlock accessing the Waste Storage unit to the Waste Nuclear Counting unit. Drums are transferred from station to station by conveyor.

Major unit equipment consists of (Figure 11.2-55):

- Two pallet conveyors in connection with the Waste Storage with fire doors,
- Overhead crane,
- Entry conveyor,
- Weighing station and conveyor,
- Gamma spectrometry station and conveyor,
- Active-Passive Neutron Examination and Assay Station (APNEA) and conveyor,
- Active-Passive Neutron Examination and Assay station,

- Exit conveyor.

Use of specific assay equipment is determined by waste characteristics. Gamma spectrometry is employed for measuring light matrices containing neutron moderating materials. The performance of APNEA examination is employed for measuring heavy matrices containing relatively small amounts of neutron moderating materials.

The unit is interconnected to the Waste Storage Unit and MMIS with its MC&A application.

11.2.3 Major Components

The major components of each unit or system are described in Section 11.2.2.

11.2.4 Control Concepts

The MP process control systems are designed to ensure that the product of the manufacturing process will conform to the product specifications with minimal waste and risk. The MP process controls are composed of normal, protective, and safety control subsystems. The normal control subsystem controls the MFFF normal manufacturing and processing operations. The protective control subsystem provides protection for personnel and equipment. The safety control subsystem is designed to ensure that safety limits will not be exceeded. Section 11.6 discusses the MFFF I&C systems in more detail.

In general, each unit is operated in automatic mode, and an automatic cycle is associated with each main function. The operator may also intercede via a manual mode in which the interlocks are active in case of trouble in the automatic mode or for maintenance operations.

The MMIS collects the information coming from all process units to control the position and the exchange of SNM as well as the traceability and the quality of the products.

11.2.5 System Interfaces

The system interfaces of each unit or system are described in Section 11.2.2.

11.2.6 Design Basis for Non-Principal SSCs

The design of the MP process is as similar as practical to the proven design currently employed at MELOX. Changes from the MELOX design result from U.S. regulatory requirements, lessons learned at MELOX, or manufacturing and throughput requirements specific to the U.S. MFFF. The MP process is designed to process 33 to 40 MT of plutonium. The throughput of the plant is based on the mission reactor reload schedule which requires an annual production of up to 149 fuel assemblies a year. Thus, the MP process area is designed for a throughput of 70 MTHM/yr.

The MP Area is designed to receive the following:

- Polished PuO_2 powder from the AP Area
- Depleted UO_2 feed powder
- Additives (poreformer agent and lubricant)

- Fuel rod cladding and hardware material
- The structure of the assemblies and other components, such as element guide tubes, instrumentation tubes, and possible specific rods
- Empty MOX fresh fuel package.

The two nuclear components entering the MP process are plutonium dioxide powder (PuO_2) and uranium dioxide (UO_2) powder. The plutonium feed powder in the MP process is PuO_2 polished in the AP process to remove gallium and americium impurities. The plutonium isotopic composition is defined as follows:

- $^{236}Pu < 1$ ng/g
- $^{238}Pu < 0.05\%$
- $90\% < {}^{239}Pu < 95\%$
- $5\% < {}^{240}Pu < 9\%$
- $^{241}Pu < 1\%$
- $^{242}Pu < 0.1\%$.

The primary impurities after polishing are as follows:

- $Ga \leq 0.1$ μg/g
- $U \leq 100$ μg/g
- $^{241}Am/(^{241}Am + Pu\ total) < 0.01\%$
- $Ag \leq 10$ μg/g.

The PuO_2 powder has a nominal specific gravity of 2.15, with a humidity of about 0.5%, and a particle size less than 100 μm. The UO_2 powder is depleted UO_2.

The intermediate products are as follows:

- Powder mixtures from which pellets are fabricated
- Pellets used to fabricate the rods
- Rods used to fabricate the assemblies
- Discarded material (scraps), which are recycled into the MP process.

Pellets are fabricated using the MELOX A-MIMAS process, which includes a two-step powder blending operation. The plutonium design content of the first blending (master mix) is approximately 20% PuO_2 maximum, and the final blending produces powder with a plutonium content as required for the fuel assembly. The nominal PuO_2 content is 6%. The MP process is designed to recycle pellets and powders, as well as material coming from rejected rods and assemblies that do not meet the product quality and specifications. The scraps are dry-recycled in the MP process. The manufactured products are MOX fuel assemblies for PWRs.

The MP Area is designed based on the following guidelines:

- Personnel and material access is through sally ports (two sally ports are dedicated to personnel access).
- MP and AP Area roofs are lined up to facilitate construction of the hardened roof.
- The MP and AP Areas share material access at level 1.
- The emergency exit is towards a safe haven.
- Personnel evacuation requirements (e.g., doors, stairwells, and airlocks) are included.
- The AP and MP Areas share HVAC and electricity supply.
- 3013 outer and inner can opening is located in the MP Area, except convenience can opening is located in the AP Area.
- Depleted UO_2 is stored in the warehouse.
- The nuclear material enters the MP Area on a loading dock.

The MOX production uses a production line that successively processes the various PuO_2 contents required for one campaign.

In the process areas that include pelletizing, sintering, grinding, pellet inspection, and cladding, the production line is duplicated for reasons of capacity, but the products processed in doubled equipment items always have the same PuO_2 content.

Downstream of rod cladding, the rod storage, rod inspection, and assembly mounting and inspection equipment are not duplicated because their respective throughput is sufficient to reach the desired production capacity.

The successive process units work at different rates or in batches, and some process steps require waiting for analytical results from the laboratory. Therefore, buffer storage is required between process steps. It is either common to several steps, like the Jar Storage and Handling Unit in the powder process and the rod storage, or specific to a given step like the pellet storage.

This organization with buffer storage allows smoothening the production in case of an anomaly in a production unit or transfer system. Buffer storage is sized accordingly.

From the buffer storage for PuO_2 containers produced by the AP process to the PuO_2 Can Emptying glove box, the production equipment and storage are in glove boxes ventilated with dry air. From the PuO_2 Can Emptying glove box to the two Rod Cladding and Decontamination Units, all production equipment and associated storage are installed in gloveboxes under inert nitrogen atmosphere in order to guarantee product quality. The exceptions are the sintering furnaces not surrounded by glove boxes and operating with a dedicated process gas (Moisturized Argon-Hydrogen mix) under slight over-pressure.

The majority of operations are automated with the exception of a very few operations, such as additive preparation and introduction, sampling, visual inspection, and pellet control.

11.2.7 Design Basis for Principal SSCs

The design basis of all the principal SSCs associated with MP Process are included and discussed with other systems.