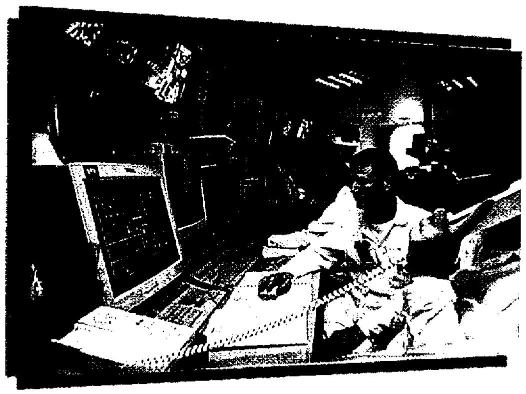
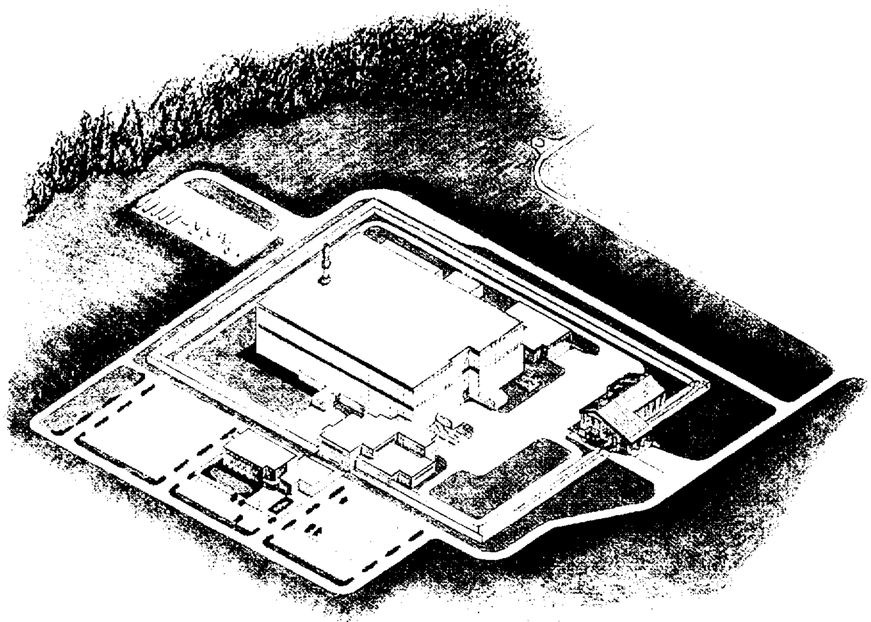
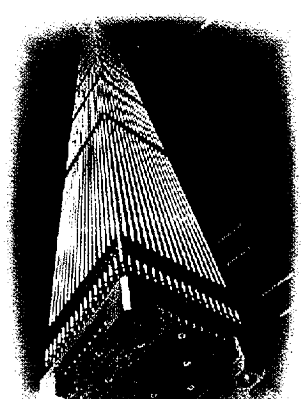
DUKE COGEMA
STONE & WEBSTER

Mixed Oxide Fuel Fabrication Facility



Construction Authorization Request





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LIST OF ACRONYMS AND ABBREVIATIONS

μ	micro
μm	micrometer
°C	degrees Celsius
°F	degrees Fahrenheit
A	ampere
AASHTO	American Association of State Highway and Transportation Officials
ac	acre
AC	alternating current
ACI	American Concrete Institute
ACL	access control list
ADCOH	Appalachian Ultadeep Core Hole
AEGL	Acute Exposure Guideline Level
AHJ	Authority Having Jurisdiction
AIHA	American Industrial Hygiene Association
AISC	American Institute of Steel Construction
ALARA	as low as reasonably achievable
ALI	annual limit on intake
ALOHA	Areal Locations of Hazardous Atmospheres
A-MIMAS	advanced micronized master blend
ANS	American Nuclear Society
ANSI	American National Standards Institute
AP	aqueous polishing
API	American Petroleum Institute
APSF	Actinide Packaging and Storage Facility
ARF	airborne release fraction
ARM	area radiation monitor
ARR	airborne release rate
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BA	Bachelor of Arts degree
BAQ	Bureau of Air Quality
BET	Bruanuer, Emmet, and Teller
BN	Belgonucleaire
BR	breathing rate
BS	Bachelor of Science degree
Btu	British thermal unit
CAAS	criticality accident alarm system
CAM	continuous air monitor
CAR	Construction Authorization Request
cc	cubic centimeter
CDE	committed dose equivalent

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

CEC	cation exchange capacity
CECP	Construction Emissions Control Plan
CEDE	committed effective dose equivalent
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cfs	cubic feet per second
CGA	Compressed Gas Association
CIF	Consolidated Incineration Facility
cm	centimeter
CM	configuration management
cm^3	cubic centimeter
CNSI	Chem Nuclear Systems, Incorporated
COCORP	Consortium for Continental Reflection Profiling
COE	U.S. Army Corps of Engineers
CPS	chemical process safety
CPT	cone penetrometer test
CPU	central processing unit
CRT	cathode ray tube
CS	conventional seismic
CSAS	Criticality Safety Analysis Sequence
CTF	Chemical Transfer Facility
DAC	derived air concentration
DBE	design basis earthquake
DBP	dibutyl phosphate
DC	direct current
DCF	dose conversion factor
DCP	Design Change Package
DCS	Duke Cogema Stone & Webster, LLC
DDE	deep dose equivalent
DE	dose equivalent
DE&S	Duke Engineering & Services, Inc.
DEAR	Department of Energy Acquisition Regulation
DER	dose equivalent rate
DETF	Dilute Effluent Treatment Facility
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-SR	U.S. Department of Energy Savannah River Operations Office
DOP	dioctyl phthalate
DR	damage ratio
DRB	Deep Rock Borings study
DUO_2	depleted uranium oxide
DWPF	Defense Waste Processing Facility
EC	effluent concentration
ECR	Engineering Change Request

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

EDMS	Electronic Data Management System
EDST	Eastern Daylight Savings Time
EIS	Environmental Impact Statement
EMMH	external man-made hazard
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration
ERPG	Emergency Response Planning Guidelines
ES&H	Environment, Safety, and Health
ETF	Effluent Treatment Facility
FEMA	failure modes and effect analysis
FHA	Fire Hazard Analysis
FIC	final isotopic composition
FM	Factory Mutual
FOCI	foreign ownership, control, or influence
fpm	feet per minute
ft	foot
g	gram
g	acceleration due to gravity
gal	gallon
gpm	gallons per minute
GSA	General Separations Area
GSAR	Generic Safety Analysis Report
ha	hectare
HAN	hydroxylamine nitrate
HAZOP	hazards and operability study
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
HEPA	high-efficiency particulate air
HFE	human factors engineering
HLW	high-level waste
HP	Health Physics
HPLC	high performance liquid chromatography
hr	hour
HIS	Human-system interface
HVAC	heating, ventilation, and air conditioning
Hz	hertz
I&C	instrumentation and control
I/O	input/output
IAEA	International Atomic Energy Agency
ICBO	International Conference of Building Officials
ICP-MS	inductive coupled plasma – mass spectroscopy
ID	identification
IDLH	Immediately Dangerous to Life and Health

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

IEEE	Institute of Electrical and Electronic Engineers
in	inch
INES	International Nuclear Event Scale
IROFS	items relied on for safety
ISA	Integrated Safety Analysis
IT/SF	Interim Treatment/Storage Facility
ITP	In-Tank Precipitation Facility
ka	kilo annum or thousands of years
kg	kilogram
kip	kilopound
km	kilometer
kV	kilovolt
L	liter
lb	pound
LDE	Lens of the Eye Dose Equivalent
LETF	Liquid Effluent Treatment Facility
LLC	Limited Liability Company
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LOC	level of severity or concern
LPF	leak path factor
m	meter
M	molar
M&O	Maintenance and Operations
m^3	cubic meter
Ma	mega annum or millions of years
MACCS2	MELCOR Accident Consequence Code System for the Calculation of the Health and Economic Consequences of Accidental Atmospheric Radiological Releases
MAR	material at risk
mb	body wave magnitude
mbar	millibar
MBP	monobutyl phosphate
MC&A	Material Control and Accounting
MCC	motor control center
MCNP	Monte Carlo N-Particle
MD	duration magnitude
meq	milliequivalent
MeV	million electron volts
MFFF	Mixed Oxide Fuel Fabrication Facility
mg	milligram
mgd	million gallons per day
mi	mile
MIMAS	micronized master blend

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

min	minute
MJ	megajoule
mm	millimeter
MMI	Modified Mercalli
MMIS	Manufacturing Management Information System
MOI	maximally exposed offsite individual
MOX	mixed oxide
MP	MOX processing
mph	miles per hour
MPQAP	MOX Project Quality Assurance Plan
MPSSZ	Middleton Place-Summerville Seismic Zone
mrem	millirem
MSA	Metropolitan Statistical Area
MSDS	Material Safety Data Sheet
msl	mean sea level
MtHM	metric tons of heavy metal
MVA	megavolt-ampere
MW	megawatt
Mw	moment magnitude
N	normal (unit of chemical concentration)
NAC/AEGL	National Advisory Committee for Acute Exposure Guidelines
nCi	nanocurie
NCSE	Nuclear Criticality Safety Evaluation
NEHRP	National Earthquake Hazards Reduction Program
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
ng	nanogram
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NO_X	nitrous fumes
NPDES	National Pollutant Discharge Elimination System
NPH	natural phenomena hazard
NRC	U.S. Nuclear Regulatory Commission
O/M	oxygen-to-metal
OML	oxalic mother liquors
OSC	Operations Support Center
OSHA	Occupational Safety and Health Administration
Pa	Pascal
PA	Protected Area
PC	performance category
pCi	picocurie
PCM	personnel contamination monitor
PDCF	Pit Disassembly and Conversion Facility
PEL	permissible exposure level

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

PEP	personnel and equipment protection
PFHA	Preliminary Fire Hazard Analysis
PGA	peak ground acceleration
PHA	Probabilistic Hazards Assessment
PIDAS	perimeter intrusion detection and surveillance
PIP	Plutonium Immobilization Plant
PLC	programmable logic controller
PMF	probable maximum flood
PMI	Positive Material Identification
PMP	probable maximum precipitation
ppb	parts per billion
ppm	parts per million
psf	pounds per square foot
PSHA	Probabilistic Seismic Hazard Assessment
psi	pounds per square inch
psia	pounds per square inch, absolute
psig	pounds per square inch, gage
PSUP	Power Services Utilization Permit
PuO_2	plutonium oxide
QA	quality assurance
QL	quality level
rad	radiation absorbed dose
RAIC	raffinates isotopic composition
RBOF	Receiving Basin for Offsite Fuels
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent, man
RF	respirable fraction
RIC	radiological isotopic composition
ROD	Record of Decision
RTF	Replacement Tritium Facility
RVT	Random Vibration Theory
RWP	Radiation Work Permit
S&W	Stone & Webster, Inc.
SA	Safety Assessment of the Design Basis
SAR	Safety Analysis Report
SC	seismic category
SCAPA	Subcommittee on Consequence Assessment and Protective Action
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCE&G	South Carolina Electric and Gas Company
SCPTU	site-specific seismic piezocone penetration test soundings
SCR	South Carolina Route
SCS	Soil Conservation Service
SDE	shallow dose equivalent

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

sec	second
SEUS	Southeastern United States
SIL	seismically induced liquefaction
SMA	strong motion accelerograph
SNM	special nuclear material
SREL	Savannah River Ecology Laboratory
SRFS	Savannah River Forest Station
SRP	Standard Review Plan
SRS	Savannah River Site
SRSS	square root of the sum of the squares
SRTC	Savannah River Technology Center
SSCs	structures, systems, or components
SSI	soil-structure interaction
SSNM	strategic special nuclear material
SST	safe secure transport
ST	source term
STEL	short-term exposure level
Sv	sievert
SWDF	Solid Waste Disposal Facility
SWMF	Solid Waste Management Facility
SWPPP	Stormwater Pollution Prevention Plan
T	trace
TBD	to be determined
TBP	tributyl phosphate
TEDE	total effective dose equivalent
TEEL	Temporary Emergency Exposure Limit
TIC	Today's Isotopic Composition
TLV	threshold limit value
TPH	hydrogenated tetrapropylene
TRU	transuranic
TWA	time-weighted average
UBC	Uniform Building Code
UCNI	Unclassified Controlled Nuclear Information
UCT	Universal Coordinated Time
UGS	Gas Storage Area
UHS	Uniform Hazard Spectrum
UIC	Underground Injection Control
UL	Underwriters Laboratory
UPS	uninterruptible power supply
USDA	U.S. Department of Agriculture
USFS	United States Forest Service
USGS	U.S. Geological Survey
UST	underground storage tank
V	volt

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

VEGP	Vogtle Electric Generating Plant
vol %	volume percent
WSI	Wackenhut Services Inc.
WSPRO	Water Surface Profile Computations
WSRC	Westinghouse Savannah River Company, LLC
wt %	weight percent
yr	year

LIST OF MFFF BUILDING AND SYSTEM DESIGNATIONS

Buildings

BAD	Administration Building
BAP	Aqueous Polishing Area
BEG	Emergency Diesel Generator Building
BMF	MOX Fuel Fabrication Building
BMP	MOX Fuel Fabrication Area (MOX Processing Area)
BRP	Reagent Processing Building
BSG	Standby Diesel Generator Building
BSH	Safe Haven Buildings
BSR	Shipping and Receiving Area
BSW	Secured Warehouse Building
BTS	Technical Support Building

Systems

BAS	Breathing Air System
CHH	HVAC Chilled Water System
CHP	Process Chilled Water System
DCE	PuO_2 Buffer Storage Unit
DCM	PuO_2 3013 Storage Unit
DCP	PuO_2 Receiving Unit
DCS	Decontamination System
DDP	UO_2 Drum Emptying Unit
DMW	Demineralized Water System
DRS	UO_2 Receiving and Storage Unit
EGF	Emergency Diesel Generator Fuel Oil System
GAH	Argon/Hydrogen System
GDE	Rod Decladding Unit
GHE	Helium System
GME, GMF	Rod Cladding and Decontamination Units
GMK	Rod Tray Loading Unit
GNO	Nitrogen Oxide System
GNS	Nitrogen System
GOX	Oxygen System
HDE	High Depressurization Exhaust System
HWS	Process Hot Water System
IAS	Instrument Air System
KCA	Oxalic Precipitation and Oxidation Unit
KCB	Homogenization Unit
KCC	Canning Unit
KCD	Oxalic Mother Liquor Recovery Unit
KDA	Decanning Unit
KDB	Dissolution Unit
KPA	Purification Cycle
KPB	Solvent Recovery Cycle

LIST OF MFFF BUILDING AND SYSTEM DESIGNATIONS (continued)

Systems

KPC	Acid Recovery Unit
KPF	Silver Recovery Unit
KWD	Liquid Waste Reception Unit
KWG	Offgas Treatment Unit
MDE	Medium Depressurization Exhaust System
NBX	Primary Blend Ball Milling Unit
NBY	Scrap Milling Unit
NCR	Scrap Processing Unit
NDD	PuO_2 Container Opening and Handling Unit
NDP	Primary Dosing Unit
NDS	Final Dosing Unit
NPE, NPF	Homogenization and Pelletizing Unit
NTM	Jar Storage and Handling Unit
NXR	Powder Auxiliary Unit
PAD	Pellet Repackaging Unit
PAR	Scrap Box Loading Unit
PFE, PFF	Sintering Units
PML	Pellet Handling Unit
POE	Process Cell Exhaust System
PQE	Quality Control and Manual Sorting Units
PRE, PRF	Grinding Units
PSE	Green Pellet Storage Unit
PSF	Sintered Pellet Storage Unit
PSI	Scrap Pellet Storage Unit
PSJ	Ground and Sorted Pellet Storage Unit
PTE	Pellet Inspection and Sorting Units
PWS	Plant Water System
RDO	Diluent System
RHN	Hydroxylamine Nitrate System
RHP	Hydrogen Peroxide System
RHZ	Hydrazine System
RMN	Manganese Nitrate System
RNA	Nitric Acid System
ROA	Oxalic Acid System
RSC	Sodium Carbonate System
RSH	Sodium Hydroxide System
RSN	Silver Nitrate System
RTP	Tributyl Phosphate System
SAS	Service Air System
SCE	Rod Scanning Unit
SDK	Rod Inspection and Sorting Unit
SEK	Helium Leak Test Unit
SGF	Standby Diesel Generator Fuel Oil System
SPS, SPC	Process Steam and Process Condensate Systems

LIST OF MFFF BUILDING AND SYSTEM DESIGNATIONS (continued)

Systems

STK	Rod Storage Unit
SXE, SXF	X-Ray Inspection Units
TAS	Assembly Handling and Storage Unit
TCK	Assembly Dry Cleaning Unit
TCL	Assembly Final Inspection Unit
TCP	Assembly Dimensional Inspection Unit
TGM	Assembly Mockup Loading Unit
TGV	Assembling Mounting Unit
TXE	Assembly Packaging Unit
VHD	Very High Depressurization Exhaust System
VRM	Radiation Monitoring Vacuum System
WVA	Vehicle Access Portal

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 approximately 20% PuO_2 content 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 maximum PuO_2 content in the final blend is 6% of the total mass. The two-step mixing process is used to ensure a consistent product.

The MP process consists of 38 process units or systems divided into five areas corresponding to the different segments of the process (see Figure 11.2-1).

<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 and 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 Container Opening and Handling Unit
- Primary Dosing Unit
- Primary Blend Ball Milling Unit
- Final Dosing Unit
- Homogenization and Pelletizing Unit
- Scrap Processing Unit
- Scrap 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 Units
- 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 Units
- 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.

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 5.5.1-2 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.

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
- 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.

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 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 and PuO_2 3013 Storage Unit

The PuO_2 Receiving Unit is located in the MOX Fuel Fabrication Building and functions to receive and open PuO_2 transport casks. The PuO_2 3013 Storage Unit is located in the MOX Process Area and functions to transfer 3013 containers from the transport cask 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)
- Transport cask (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) vehicle. The SST vehicle contains casks palletized on CRTs. Several casks (SAFKEG or 9975 type) are loaded on each CRT, and five CRTs are loaded on each truck.

Each cask 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 cask 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. The transportation casks are removed from the CRT and then moved to the cask opening station located in the MOX Process Area. During SST vehicle receipt and CRT unloading, security inspections, package identification, and health protection controls are performed. Accountability data are logged in the Material Control and Accounting (MC&A) system.

The cask 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.

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 cask 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 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 432 pits. Four 3013 containers can be placed in each pit for a total of 1,728 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 Receiving Unit and PuO_2 3013 Storage Unit interface 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 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 Container Opening and Handling Unit, receives and stores empty cans, and transfers them back to the AP PuO_2 Canning Unit. 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 144 cans in four rows of 18 wells with two 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 Container Opening and Handling Unit or transferred to the storage glovebox. Empty PuO_2 cans are returned from the PuO_2 Container Opening and Handling 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 two 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. Cans are transferred between the transfer and buffer storage gloveboxes through the buffer storage airlock.

The PuO_2 Buffer Storage Unit interfaces with the AP PuO_2 Canning Unit, the PuO_2 Container Opening and Handling Unit, and the facility MC&A system.

11.2.2.5 PuO_2 Container Opening and Handling Unit

The function of the PuO_2 Container Opening and Handling Unit is to receive cans of purified PuO_2 and empty the cans onto a vibrating conveyor supplying the dosing unit. The unit also performs can weighing and can 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
  - Emptying flywheel with impactor
  - PuO_2 collecting funnel

- Connection glovebox with vibrating channel

- Transfer glovebox with manual gripper, can opening/closing device, and dust removal system.

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. The empty can to be replaced is weighed and identified in the receiving glovebox and conveyed 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. The can lid is removed, and dust is removed from the can body and lid with the dust removal system. 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 Container Opening and Handling Unit interfaces with the primary dosing glovebox, the PuO_2 Buffer Storage Unit, the MC&A system, and the control display in the control room.

11.2.2.6 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 PuO_2 content of the primary blend is a maximum of 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
- Jar lift with two tilting devices
- Conveyor system
- Dosing scale and associated electronics

- TV cameras
- Vacuum extractor with filtering and collection devices
- 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 J60 jar coming from the Jar Storage and Handling Unit.

- PuO_2 powder transferred to the inner 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, in 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 pots from the round basket holding five pots
- Weighing and identifying the empty 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 big hopper is performed independently according to the signals from the high- and low-level detectors. The jar is then sent back to the Jar Storage and Handling Unit, weighed, and identified.

Alternately, 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 pots is transferred from the PuO_2 Container Opening and Handling Unit to the vibrating conveyor and poured into the inner 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 dedicated J60 jar in the Jar Storage and Handling Unit is transferred to the unit through the connection module where it is weighed and identified.

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

11.2.2.7 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):

- Jar lid removal, jar weighing, and bar code reader identification systems
- Conveyor system
- 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
- Vacuum extractor
- 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 J60 jar is disconnected, lowered into its shielding, weighed, and stored in the Jar Storage and Handling Unit before being 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 MC&A application. It has its own monitoring system in the control room.

11.2.2.8 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 design maximum 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 lifts and their tilting devices
- Conveyor system
- Dosing scale

- 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 J60 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 filled and weighed on a continuous basis.

The precision scale on which the J80 jar stands performs the dosing operation. Vibrating conveyors 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.

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

The Final Dosing Unit interfaces with Jar Storage and Handling Unit, the UO_2 Drum Emptying Unit and the manufacturing management and information system (MMIS) system with its embedded MC&A application. It also has its own supervisory system in the control room.

11.2.2.9 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 with its jar scale and lid removal
- Jar handling with its conveyor, lift, and jar tilter

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- Additive feeding station for stearate (lubricant) hopper, vibrating conveyor, and poreformer hopper

( )

- Press shoe and associated hoses
- 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

( )

- 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 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 and identified. This operation is repeated until the required quantity of MOX powder is transferred to the mixer.

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, in addition to the MC&A system. The Homogenization and Pelletizing Unit has its own monitor in the control room.

11.2.2.10 Scrap Processing Unit

The Scrap Processing Unit functions to recycle plutonium-containing waste scrap 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 green and 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 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 lift with tilter
- Conveyor system
- Dosing station
- Discarded pellet line with stainless steel box tilter, vibrating conveyors, bowl feeder, crusher, and loading tube
- Stainless steel box lift
- Turning arm
- Two linear conveyors
- Pot scale for manual weighing
- Bar code reader
- TV cameras
- Dust collection network
- 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. The discarded pellets are crushed and sent to the Primary Blend Ball 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.

The unit prepares the recyclable products in two lines: one for discarded pellets and one for discarded powders. Both lines function to identify and weigh all incoming/outgoing containers from/to the Jar Storage and Handling Unit and the Scrap Pellet Storage Unit.

In 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 at the upper level:

- Transferring pots between the round basket on the lift 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.

11.2.2.11 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.

11.2.2.12 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.

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

- Connection module
- Jar and round basket lift
- 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.

In 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 MC&A application. It has its own monitor in the control room, as well as a local control cabinet on the unit work floor.

11.2.2.13 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 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. Another 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.

In 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 with the MC&A application.

11.2.2.14 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
- 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 MC&A application.

11.2.2.15 Sintering Units

The functions of the Sintering Units are as follows:

- Receive incoming boats (i.e., Mo-boats) loaded with green pellets
- 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
- Temporarily store the boats
- Transfer the boats to the Sintered Pellet Storage Unit.

The two identical Sintering Units remove the lubricant and the poreformer in the pellets in a preheating section and then sinter the pellets. The sintering process is performed by heat treatment of green pellets under a scavenging gas (mix of argon, hydrogen, and moisture). The last section of the furnaces is for cooling.

Green pellet boats are positioned on a molybdenum shoe and then transferred to the furnace. Inlet and outlet airlocks are required for atmospheric changes. A pusher system provides continuous motion of the boat on the shoe stack through the furnace. The last set introduced into the furnace pushes the preceding ones. Boats are identified and weighed when they enter and leave the furnaces. 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 under a slight overpressure to prevent oxygen from entering the furnaces. 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 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 lift 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.

The furnace cooling network has interfaces with the following utilities:

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

Controls on the furnace outer shell and in the cooling network keep the furnace shell temperature within limits.

11.2.2.16 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 Green Pellet Storage Unit, the two Grinding Units, the Pellet Repackaging Unit, the Scrap Box Loading Unit, the two Quality Control and Manual Sorting Units, 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.

11.2.2.17 Grinding Units

The functions of the Grinding Units are as follows:

- Grind sintered pellets to the diameter specified for finished pellets

- 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 MC&A application.

11.2.2.18 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 the same 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, each storage compartment can accommodate a stainless steel box of scrap pellets or two dust pots, for a maximum capacity of approximately 201 containers.

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

11.2.2.19 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
- Visually inspect and measure each pellet
- Place accepted pellets into a tray
- Place rejected pellets into a stainless steel box
- 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.

11.2.2.20 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
- Diameter measurement
- Length measurement
- Perpendicularity measurement

- Weight measurement.

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

- Scale
- ATI machine (for diameter, length, and perpendicularity measurements)
- Laser micrometer.

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 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.

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 MC&A application.

11.2.2.21 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 MC&A application.

11.2.2.22 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.

11.2.2.23 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 Ground and Sorted Pellet Storage Unit, the Scrap Processing Unit, the filter maintenance glovebox, and the MMIS with its embedded MC&A application.

11.2.2.24 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.

11.2.2.25 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.

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

The first station (rod filling station) includes 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).

One of the two Rod Cladding and Decontamination Units is fitted with an additional station for repairing the rod upper plug in case of a welding nonconformity (see Figure 11.2-35). The rods to be repaired are introduced into the rod handling glovebox and transferred to this repair station

where 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.

After loading a rod tray with rods, full trays are placed into the Rod Storage Unit. The two Rod Cladding and Decontamination Units share the rod tray loading station (see Figure 11.2-36). 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 Units interface with the pellet handling system, the Rod Tray Loading Unit, and the MC&A application.

11.2.2.26 Rod Tray Loading Unit

The Rod Tray Loading Unit serves the two lines (i.e., rod cladding and decontamination). The Rod Tray Loading Unit contains the following equipment:

- Two travelling conveyors
- Two loading stations
- 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.

11.2.2.27 Rod Storage Unit

The functions of the 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 Storage Unit is used by the Rod Cladding and Decontamination Units, 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 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 seven concrete storage compartments, each of which contains a tray storage rack. 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 Storage Unit is fully automated and supervised by an operator from the control room.

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

11.2.2.28 Helium Leak Test Unit

The function of the Helium Leak Test Unit is to check the leaktightness 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.

11.2.2.29 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 pellet alignment 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.

11.2.2.30 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.

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.

11.2.2.31 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.

11.2.2.32 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 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.

11.2.2.33 Assembly Mockup Loading Unit

The function of the Assembly Mockup Loading Unit is to place the rod bundle in the correct configuration before inserting the assembly 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 Assembly Mockup Loading Unit interfaces with the Assembly Mounting Unit, the Rod Tray Loading Unit and the MC&A application.

11.2.2.34 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. 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 assembly structure is visually inspected and transferred to the upending fixture for installation.

Rods located in the mockup are inserted using a pulling fixture and tie rods. 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 disengaged.

After pulling of all fuel rods, the assembly ends are put in place and the assembly guide tubes are crimped onto the bottom end. The assembly is then 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 as all the other units.

11.2.2.35 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.

11.2.2.36 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.

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.

11.2.2.37 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 travelling 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 with its calibrated spring box and mobile gripper storage rack
- Gripper spring calibration machine.

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 MC&A application.

11.2.2.38 Assembly Packaging Unit

The main function of the Assembly Packaging Unit 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.

As shown on Figure 11.2-50, each shipping cask is able to transport three assemblies. 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.

11.2.3 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 maximum PuO_2 design 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.

[ ]

- SST trucks do not enter the MP Area. The nuclear material enters the MP Area on a loading dock.

[redacted]

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 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 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.

Figures

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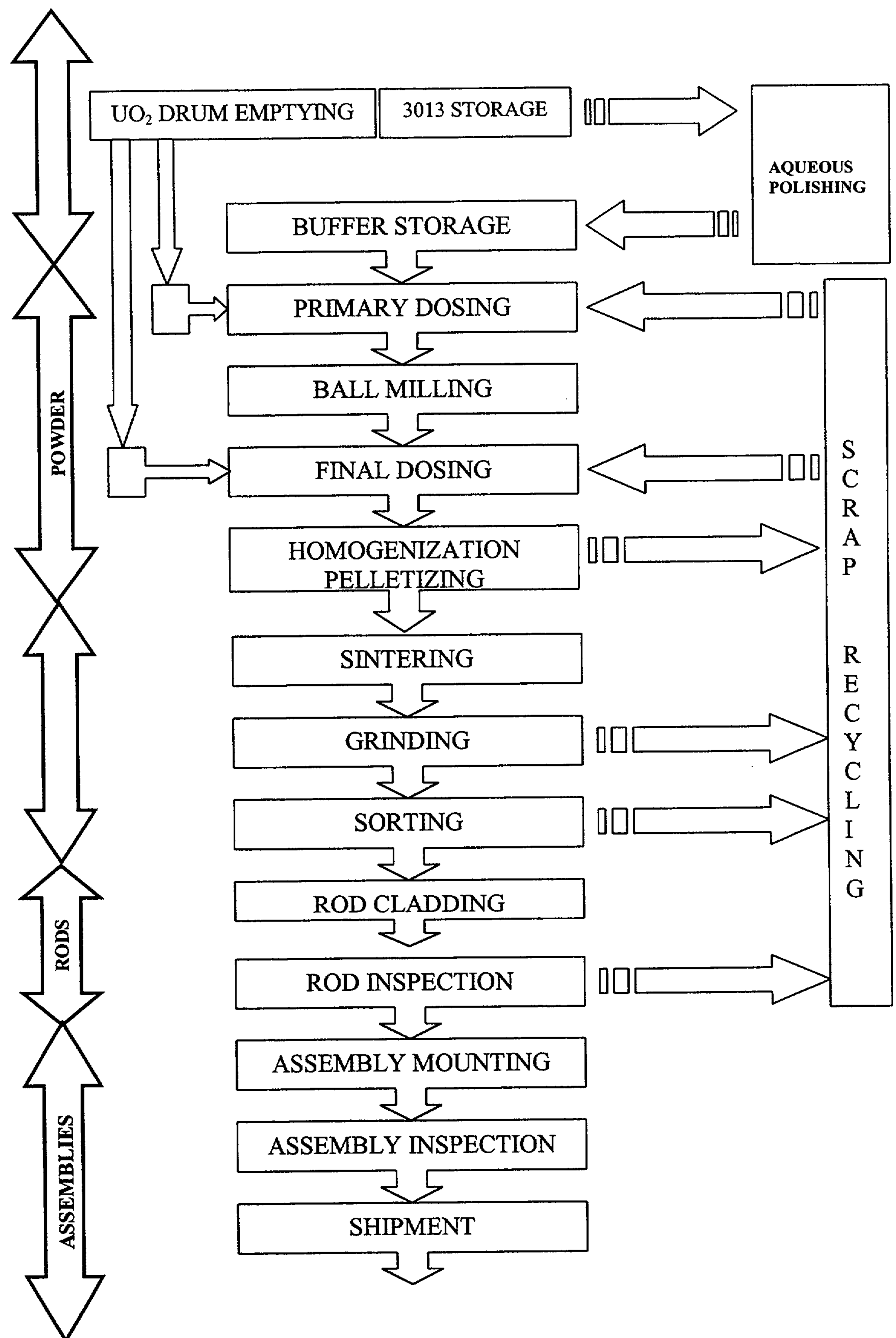

Figure 11.2-1. MOX Process Diagram

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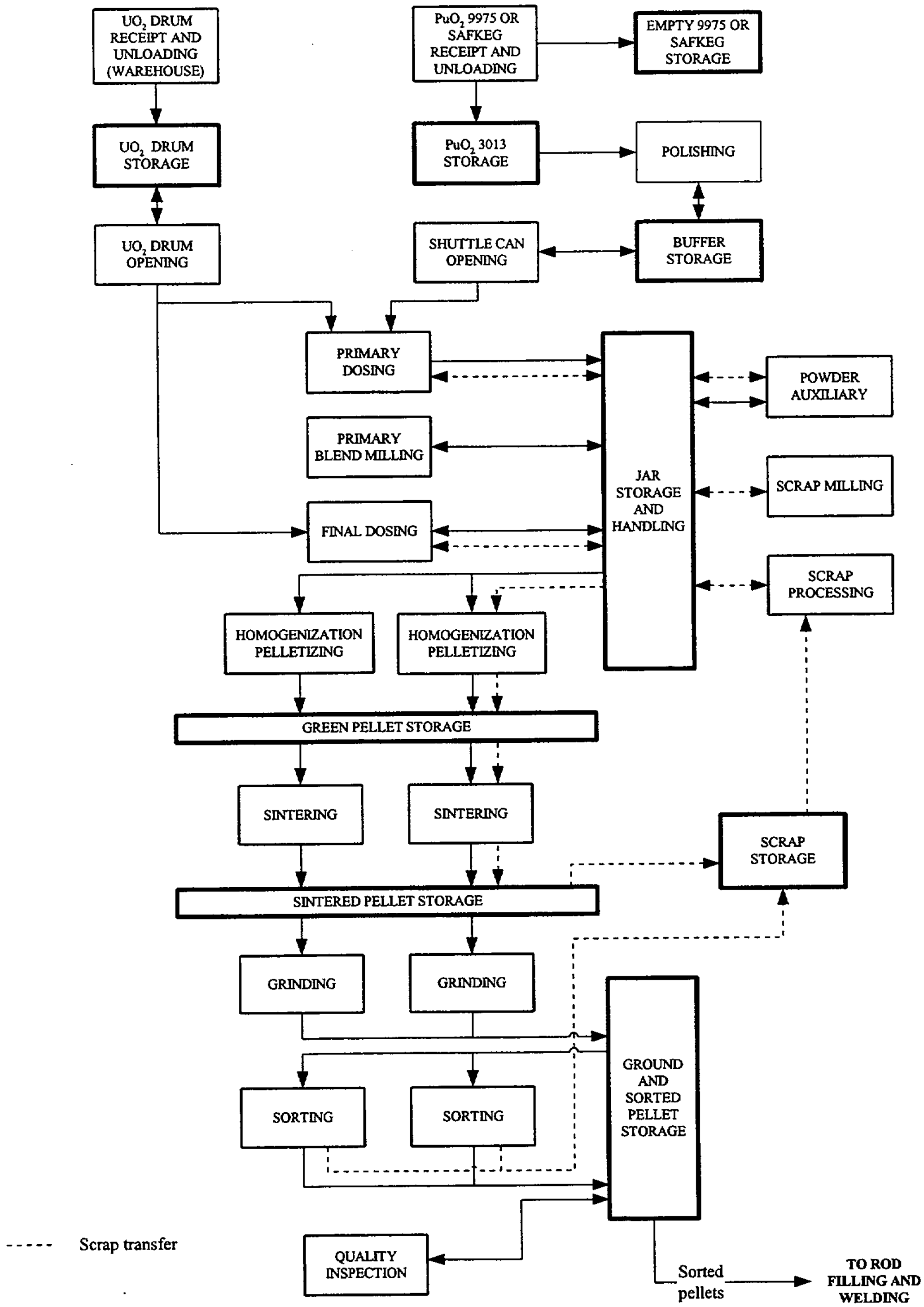

Figure 11.2-2. First Part of the Production Line – Detailed Diagram

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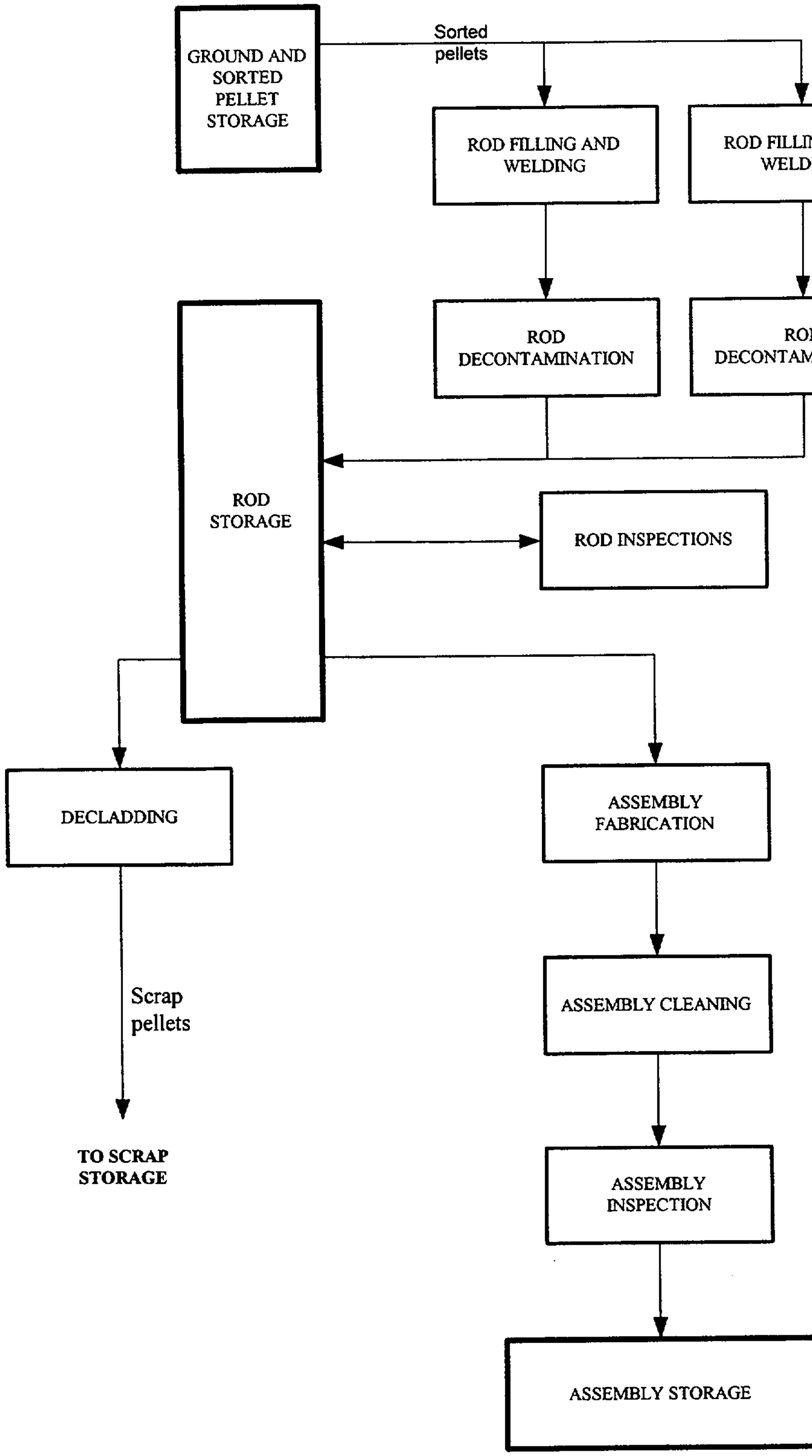

Figure 11.2-3. Second Part of the Production Line – Detailed Diagram

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Figure 11.2-4. UO_2 Drum Emptying Unit

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Figure 11.2-4. UO_2 Drum Emptying Unit (continued)

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Figure 11.2-5. Composition of a Cask

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Figure 11.2-6. PuO_2 Buffer Storage Unit

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Figure 11.2-6. PuO_2 Buffer Storage Unit (continued)

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Figure 11.2-7. PuO_2 Container Opening and Handling Unit

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Figure 11.2-7. PuO_2 Can Opening Unit (continued)

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Figure 11.2-8. Primary Dosing Unit

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Figure 11.2-8. Primary Dosing Unit (continued)

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Figure 11.2-9. Primary Blend Ball Milling Unit

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Figure 11.2-9. Primary Blend Ball Milling Unit (continued)

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Figure 11.2-10. Final Dosing Unit

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Figure 11.2-10. Final Dosing Unit (continued)

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Figure 11.2-11. Homogenization and Pelletizing Unit

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Figure 11.2-11. Homogenization and Pelletizing Unit (continued)

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Figure 11.2-12. Scrap Processing Unit

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Figure 11.2-12. Scrap Processing Unit (continued)

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Figure 11.2-13. Powder Auxiliary Unit

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Figure 11.2-13. Powder Auxiliary Unit (continued)

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Figure 11.2-14. Jar Storage and Handling Unit (Top View). See Figure 11.2.-15 for index.

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Figure 11.2-15. Jar Storage and Handling Unit (Side View)

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Figure 11.2-15. Jar Storage and Handling Unit (continued)

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Figure 11.2-16. Green Pellet Storage Unit

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Figure 11.2-16. Green Pellet Storage Unit (continued)

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Figure 11.2-17. Sintering Unit – Top View

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Figure 11.2-18. Sintering Unit – Section

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Figure 11.2-19. Grinding Unit – Supply Glovebox

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Figure 11.2-19. Grinding Unit – Supply Glovebox (continued)

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Figure 11.2-20. Grinding Unit – Grinding and Laser Cleaning Gloveboxes

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Figure 11.2-20. Grinding Unit – Grinding and Laser Cleaning Gloveboxes (continued)

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Figure 11.2-21. Grinding Unit – Basket Filling Glovebox

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Figure 11.2-21. Grinding Unit – Basket Filling Glovebox (continued)

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Figure 11.2-21. Grinding Unit – Basket Filling Glovebox (continued)

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Figure 11.2-22. Pellet Inspection and Sorting Unit – Sorting Glovebox

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Figure 11.2-22. Pellet Inspection and Sorting Unit – Sorting Glovebox (continued)

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Figure 11.2-23. Pellet Inspection and Sorting Unit – Basket Loading Glovebox

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Figure 11.2-23. **Pellet Inspection and Sorting Unit Basket Loading Glovebox (continued)**

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Figure 11.2-24. Quality Control and Manual Sorting Unit – Handling and Re-sorting Glovebox

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Figure 11.2-25. Quality Control and Manual Sorting Unit - Quality Control Glovebox

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Figure 11.2-25. Quality Control and Manual Sorting Unit – Quality Control Glovebox (continued)

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Figure 11.2-26. Scrap Box Loading Unit

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Figure 11.2-26. Scrap Box Loading Unit (continued)

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Figure 11.2-27. Pellet Repackaging Unit

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Figure 11.2-27. Pellet Repackaging Unit (continued)

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Figure 11.2-28. Pellet Handling System

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Figure 11.2-29. Rod Cladding and Decontamination Units – General Arrangement

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Figure 11.2-30. Rod Cladding and Decontamination Unit – Rod Handling Glovebox

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Figure 11.2-31. Rod Cladding and Decontamination Unit – Stack Preparation Glovebox and Tube Filling Glovebox. See Figure 11.2-32 for index.

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Figure 11.2-32. Rod Cladding and Decontamination Unit – Cleaning Glovebox and Plugging Glovebox

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Figure 11.2-32. Rod Cladding and Decontamination Unit (continued)

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Figure 11.2-33. Rod Cladding and Decontamination Unit – Welding Glovebox

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Figure 11.2-34. Rod Cladding and Decontamination Unit – Decontamination Unit

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Figure 11.2-35. Rod Cladding and Decontamination Unit – Repair Unit

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Figure 11.2-35. Rod Cladding and Decontamination Unit – Repair Unit (continued)

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Figure 11.2-36. Rod Cladding and Decontamination Unit – Tube Introduction Unit

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Figure 11.2-37. Rod Storage Unit (Section).
Index table: see Figure 11.2-38 continued.

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Figure 11.2-38. Rod Storage Unit (Top View)

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Figure 11.2-38. Rod Storage Unit (continued)

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Figure 11.2-39. Helium Leak Test Unit

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Figure 11.2-39. Helium Leak Test Unit (continued)

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Figure 11.2-40. X-Ray Inspection Unit

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Figure 11.2-40. X-Ray Inspection Unit (continued)

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Figure 11.2-41. Rod Scanning Unit

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Figure 11.2-41. Rod Scanning Unit (continued)

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Figure 11.2-42. Rod Inspection and Sorting Unit

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Figure 11.2-42. Rod Inspection and Sorting Unit (continued)

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Figure 11.2-43. Rod Decladding Unit

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Figure 11.2-43. **Rod Decladding Unit (continued)**

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Figure 11.2-44. Assembly Mockup Loading Unit

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Figure 11.2-44. Assembly Mockup Loading Unit (continued)

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Figure 11.2-45. Assembling Mounting Unit

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Figure 11.2-45. Assembly Mounting Unit (continued)

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Figure 11.2-46. Assembly Dry Cleaning Unit

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Figure 11.2-46. Assembly Dry Cleaning Unit (continued)

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Figure 11.2-47. Assembly Dimensional Inspection Unit

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Figure 11.2-48. Assembly Final Inspection Unit

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Figure 11.2-48. Assembly Final Inspection Unit (continued)

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Figure 11.2-48. Assembly Final Inspection Unit (continued)

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Figure 11.2-48. Assembly Final Inspection Unit (continued)

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Figure 11.2-49. Assembly Handling and Storage Unit

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Figure 11.2-49. Assembly Handling and Storage Unit (continued)

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Figure 11.2-49. Assembly Handling and Storage Unit (continued)

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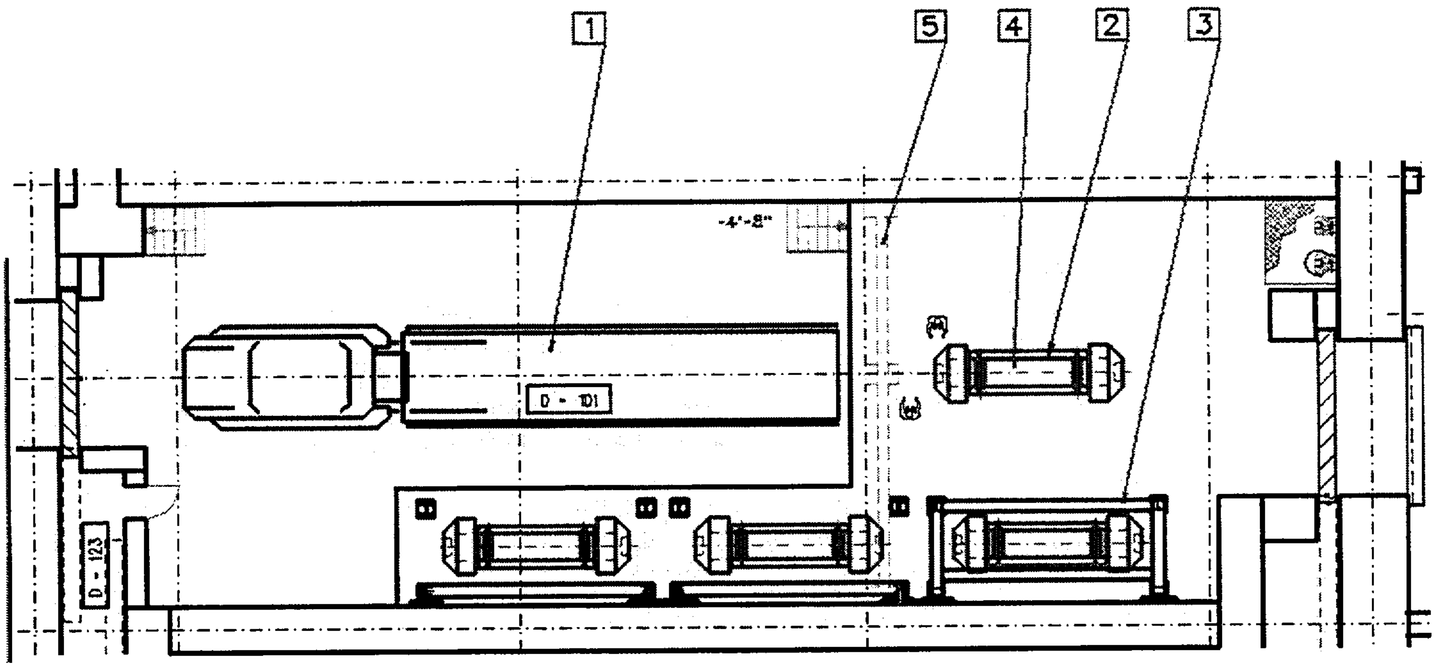
SST LOADING OPERATION



STRONGBACK LOADING OPERATION

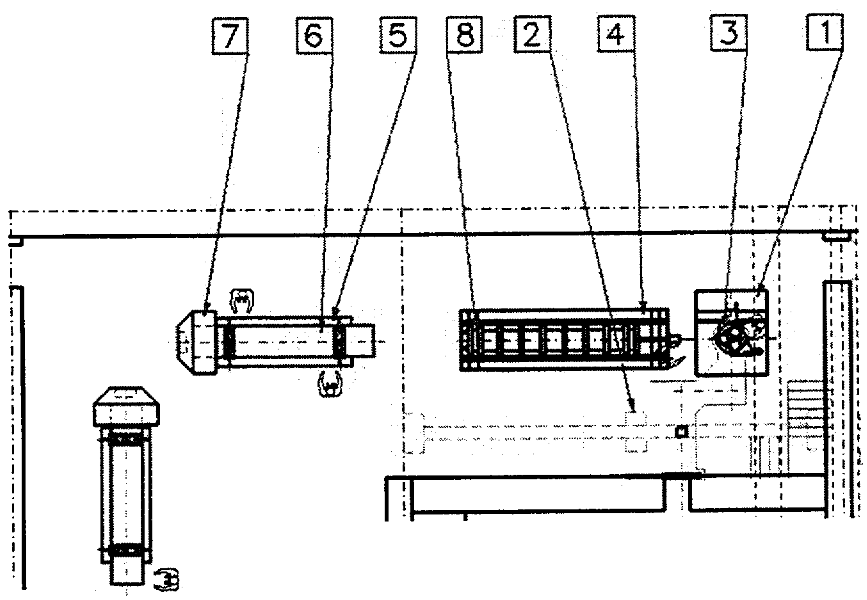


Figure 11.2-50. Assembly Packing Unit

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SST LOADING OPERATION

Ref.	Item	Observation
1	SST trailer	Capacity: One MOX Fresh Fuel Package
2	Air pallet	Capacity: 15,000 pounds
3	Storage rack	6 positions
4	Mox Fresh Fuel Package	Capacity: 3 MOX assemblies
5	Handling overhead crane	Capacity: 20,000 pounds

STRONGBACK LOADING OPERATION

Ref.	Item	Observation
1	Access platform	
2	Handling overhead crane	Capacity: 2,000 pounds
3	Strongback handling station	Vertical position, ready for strongback loading operation
4	Strongback handling station	Horizontal position, ready for MOX Fresh Fuel Package loading / unloading operation
5	Mox Fresh Fuel Package	Capacity: 3 MOX assemblies
6	Air pallet	Capacity: 15,000 pounds
7	Impact limiter	
8	Strongback	Capacity: 3 MOX assemblies

Figure 11.2-50. Assembly Packing Unit (continued)

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11.3 AQUEOUS POLISHING PROCESS DESCRIPTION

This section provides a description and overview of the Aqueous Polishing (AP) Process, 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 AP Process.

11.3.1 Function

The function of the AP process is to remove impurities from the feed plutonium of the Pit Disassembly and Conversion Facility (PDCF) for use in the MOX Processing (MP) Area. The AP process extracts impurities, predominantly gallium and americium, from the weapons-grade plutonium dioxide. The safety function of the principal SSCs associated with the AP process is discussed in Chapter 5.

11.3.2 Description

The AP process consists of 13 process units or systems:

- Decanning Unit
- Dissolution Unit
- Purification Cycle
- Solvent Recovery Cycle
- Oxalic Precipitation and Oxidation Unit
- Homogenization Unit
- Canning Unit
- Oxalic Mother Liquor Recovery Unit
- Acid Recovery Unit
- Silver Recovery Unit
- Offgas Treatment Unit
- Liquid Waste Reception Unit
- Sampling System.

Figure 11.3-1 provides an overview of the AP process, and Figure 11.3-2 shows the AP general process diagram. In general, the AP process involves three major steps:

- **Dissolution of PuO_2 powder by electro-generated Ag(II)** – The dissolution step involves silver-catalyzed dissolution and filtration. This process was selected because it is very efficient and independent of PuO_2 powder characteristics. It results in the complete dissolution of the PuO_2 powder according to kinetics governed solely by the rate of Ag(II) generation. PuO_2 powder is dissolved by electro-generated Ag(II) in a nitric acid medium. This process takes place at normal temperature (68°F to 104°F [20°C to 40°C]). The silver is recovered in a separate electrolyzer to be reused in the dissolution step.

- **Plutonium purification by solvent extraction** – The purification step involves plutonium extraction, solvent regeneration, and acid recovery. This process was selected because it yields very little plutonium leakage and has a high gallium decontamination factor.
- **Conversion into PuO_2 by continuous oxalate calcination** – The conversion process is a continuous oxalate conversion process. This process was selected because it yields a PuO_2 powder routinely used for MOX fabrication. Conversion to PuO_2 involves several operations: oxalic precipitation and oxidation (which includes precipitation, filtration, and drying and calcination), PuO_2 homogenization, PuO_2 canning, and oxalic mother liquor recovery.

The following sections discuss the 13 AP process units or systems.

11.3.2.1 Decanning Unit

11.3.2.1.1 Function

The function of the Decanning Unit is to remove the PuO_2 powder from the 3013 cans.

11.3.2.1.2 Description

The Decanning Unit consists of a series of workstations and gloveboxes distributed between the MP and AP Areas. The cans are transported between the two areas by a pneumatic transfer system. PuO_2 3013 containers are opened, emptied, metered, and fed to the electrolyzers of the Dissolution Unit.

The process is entirely mechanical. The container consists of three stainless steel containers: an outer can containing an inner can that contains the convenience can with PuO_2 powder. All can opening and powder transfer operations are fully automatic. The outer can is opened in the MP Area and pneumatically transferred to the AP Area. The inner can and the convenience can are opened in a glovebox in the AP Area, and the contents are fed into the hoppers in the Decanning Unit. Most of the process operations are conducted in gloveboxes. The unit is designed to supply the electrolyzer with three cans (approximately 13.5 kg) of PuO_2 powder per dissolution batch. The waste packages consist of the outer can, which is transported to the PDCF, and the inner can and the convenience can, which are transferred to waste storage.

The Decanning Unit is subdivided into one workstation and nine gloveboxes. Each subassembly ensures one or more functions. The functional breakdown is as follows:

- Outer can opening station
- Airlocks (glovebox)
- Inner can opening glovebox
- Pneumatic transfer glovebox (departure)
- Pneumatic transfer glovebox (arrival: Lines 1 and 2)
- Convenience can opening glovebox (Lines 1 and 2)
- Dosing hopper glovebox (Lines 1 and 2).

The mechanical processes implemented in the gloveboxes and pneumatic transfer system are described in Section 11.7.

The automatic functions at this workstation include all the outer transfer can and opening operations needed to withdraw the inner can, including identification of the bar code on the outer can surface and opening of the outer can lid using a cutter wheel. The outer can is docked to an airlock where it is held beneath a guillotine door. An inflatable seal around the outer can ensures a leaktight seal, and the guillotine door is opened without breaching the airlock containment since the internal volume of the outer can becomes an extension of the airlock volume.

The outer can is checked for contamination immediately after removal of the lid. If the outer can is contaminated, the cycle is interrupted, the outer can is manually removed, and the lid-cutting mechanism is decontaminated.

The convenience can is received from the pneumatic transfer arrival glovebox via an airlock and weighed prior to emptying the powder. The can opening and pressing machine opens the convenience can. The tilter overturns the convenience can to empty the can of PuO_2 powder. The can interior is cleaned with a dedusting system. The clean empty can with its lid placed inside is compacted with the can opening and pressing machine. The compacted cans are stored on a carrousel pending manual removal by an operator.

11.3.2.1.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.1.4 Process Equipment

Figure 11.3-3 provides a simplified drawing of the Decanning Unit.

11.3.2.1.5 Chemical Process Inventories

The normal inventory of radionuclides involved in this unit is provided in Table 11.3-1.

11.3.2.1.6 Chemical Process Ranges

This section is not applicable to this unit.

11.3.2.1.7 Chemical Process Limits

This section is not applicable to this unit.

11.3.2.2 Dissolution Unit

11.3.2.2.1 Function

The function of the Dissolution Unit is to dissolve the PuO_2 powder.

11.3.2.2.2 Description

The PuO_2 is electrolytically dissolved in the Dissolution Unit to separate impurities (specifically americium, gallium, and uranium) in the Purification Cycle. The powder from the hopper is gradually fed into the electrolyzer by the screw conveyor.

Samples from the dilution and sampling tank are analyzed to determine the fissile material content and the required degree of dilution before being sent to the Purification Cycle feed tank. The Dissolution Unit processes approximately 12 kg of plutonium per batch.

The Dissolution Unit consists of two identical processing lines. The cadmium-lined hopper and the screw conveyors are installed on scales in a glovebox. The PuO_2 powder is fed into the hopper. The total and the differential weights per unit of time are continuously recorded. The instantaneous flow is computed and compared with the setpoint, and the flow rate is calibrated by the speed of the screw.

Ag^{2+} ions are electrolytically produced in the cylindrical compartment.

The cathode well from a nitric acid slab tank is fed by an airlift via a drip pot. The cathode well overflows into the slab tank via another drip pot. The electrolysis cell solution flows into a complementary pot and the flat powder-receiving compartment.

The powder-receiving compartment is connected to the powder feed screw conveyor by a chute, which is provided with a branch for unblocking it, a valve to prevent moisture from rising and powder from falling in after completion of electrolysis, and impacters to facilitate powder transfer to the Dissolution Unit.

A turbine is used to circulate the dissolution solution.

- Draining of the analyte circuit containing the dissolution solutions into receiving tank 3000 (or tank 4000). The dissolution solution is drained off by pump and then filtered in a Poral filter and transferred to receiving tank 3000 (or tank 4000).
- Draining of the cathode well into the electrolyzer anode section. The solution is transferred by suction produced by the air jet and electrolyzer overflow line to tank 3000 (or tank 4000).
- Filling of tank 1500 (or tank 2500) with water to dilute the catholyte.
- Draining of tank 1500 (or tank 2500) into tank 3000 (or tank 4000). The solution is transferred by an airlift and the electrolyzer overflow line.

Receiving tank 3000 (or tank 4000) receives the electrolyzer dissolution solution after filtering and the rinsing solution drained from electrolyzer 1000 (or electrolyzer 2000) and the electrolyzer overflow.

In normal operation, draining solutions received in receiving tank 3000 (or tank 4000) are transferred to dilution and sampling tank 5000 (or tank 6000) via a pump and filter. Dilution and sampling tank 5000 (or tank 6000) is made of 316L stainless steel and has a useful volume of 106 gal (400 L). This tank is used for diluting the dissolution solution to reduce the plutonium and ^{235}U concentrations before recycling in the process and to establish the fissile material balance. The fissile material balance is established based on the plutonium concentration as determined by analysis and measurement of the volume. Dilution and sampling tank 5000 (or tank 6000) is equipped with a concentrated, depleted uranyl nitrate inlet; a nitric acid/water inlet via a static mixer; two internal mixing airlifts to homogenize the solution; and a sampling line via an airlift.

After dilution and sampling, the solutions are transferred via siphon to buffer tank 7000, which receives the contents of two dissolution batches (one PuO_2 lot) before transfer to the Purification Cycle. This tank is common to the two processing lines. The tank is made of 316L stainless steel, has a useful volume of 185 gal (700 L), and is geometrically safe (annular). In normal operation, the solutions are transferred (by airlift) to Purification Cycle tank 1000. Buffer tank 7000 is equipped with a sparging ring.

11.3.2.2.3 Process Chemistry

PuO_2 powder, which is insoluble in a purely nitric medium, is put into solution by electrolytic dissolution with Ag^{2+}. The electrolytic dissolution takes place in a 6N nitric acid solution at 86°F (30°C). The general process whereby PuO_2 is dissolved by the electrolytically produced Ag^{2+} is as follows.

Electrolytic production of Ag^{2+}:

$$Ag^{+} \rightarrow Ag^{2+} + e^{-} \qquad (11.3\text{-}1)$$

Dissolution of PuO_2 powder:

$$PuO_2\text{ (solid)} + Ag^{2+} \rightarrow PuO_2^{+}\text{ (solid)} + Ag^{+} \quad (11.3\text{-}2)$$

$$PuO_2^{+}\text{ (solid)} \xrightarrow{HNO_3} PuO_2^{+}\text{ (solution)} \quad (11.3\text{-}3)$$

$$PuO_2^{+}\text{ (solution)} + Ag^{2+} \rightarrow PuO_2^{2+}\text{ (solution)} + Ag^{+} \quad (11.3\text{-}4)$$

Giving the following general reaction:

$$PuO_2\text{ (solid)} + 2Ag^{2+} \rightarrow PuO_2^{2+}\text{ (solution)} + 2Ag^{+} \quad (11.3\text{-}5)$$

Ag^+ ions are oxidized at the anode. The following reduction reaction takes place at the cathode:

$$NO_3 + 3H^+ + 2e^- \rightarrow HNO_2 + H_2O \quad (11.3\text{-}6)$$

Dissolution occurs when a current is applied. The joule effect of the electrical power supplied is attenuated by cooling the analyte.

11.3.2.2.4 Process Equipment

Figures 11.3-4 and 11.3-5 provide simplified drawings of the Dissolution Unit and the electrolyzer, respectively.

11.3.2.2.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-2 and 11.3-3, respectively.

11.3.2.2.6 Chemical Process Ranges

The Dissolution Unit is operated in batches. The Dissolution Unit is designed to treat 22 kg/day of PuO_2. The operating range of the Dissolution Unit is 14 PuO_2 kg/week (one dissolution per week) to 173 PuO_2 kg/week (two lines operating at six batches each per week). The nominal flow rate to the Purification Cycle is approximately 15 L/hr (min: 2 L/hr, max: 21 L/hr).

11.3.2.2.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.2.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.3 Purification Cycle

11.3.2.3.1 Function

The main goal of the Purification Cycle is to separate plutonium from impurities contained in the flux coming out of the Dissolution Unit. The main functions of the Purification Cycle are as follows:

- Receive plutonium nitrate from the Dissolution Unit
- Perform plutonium extraction and impurities scrubbing
- Perform plutonium stripping and diluent washing
- Perform plutonium stripping in plutonium barrier
- Perform uranium stripping and diluent washing
- Adjust plutonium to the tetravalent state
- Receive, control, recycle, and transfer plutonium to the Oxalic Precipitation and Oxidation Unit
- Wash, control, and transfer raffinates diluent to the Acid Recovery Unit
- Receive recycled plutonium nitrate from the Oxalic Mother Liquor Recovery Unit.

11.3.2.3.2 Description

The Purification Cycle is designed to treat plutonium nitrate at a nominal flow rate of 4 gal/hr (15.1 L/hr), which corresponds to 14.4 kg/day of plutonium. Plutonium nitrate from the Dissolution Unit is received, and plutonium is extracted and scrubbed for impurities. The plutonium with uranium left in the stream is stripped after adjustment of the plutonium valence to the trivalent state. The Purification Cycle controls plutonium reception, recycle, and transfer to the Oxalic Precipitation and Oxidation Unit. The Purification Cycle also controls the solvent and diluent streams to the Solvent Recovery Cycle and the raffinate stream to the Acid Recovery Unit.

The extraction process is continuous, but the feed solutions from the Dissolution Unit are received in batches. The raffinate and the plutonium nitrate solutions are transferred continuously to the Acid Recovery Unit inlet buffer storage and to the Oxalic Precipitation and Oxidation Unit inlet buffer storage, respectively.

Plutonium nitrate solution is batched to the feed tank for plutonium extraction and impurities scrubbing. Pu(IV) in the aqueous solution (4.5N HNO_3) is extracted by the solvent (30% tributyl phosphate [TBP] in branched dodecane) in a pulsed extraction column. The impurities remain primarily in the aqueous phase. The solvent stream is scrubbed by 1.5N nitric acid in a pulsed scrubbing column to ensure good decontamination. The aqueous raffinates are washed by the diluent in a pulsed column and transferred to the raffinate reception tank.

Pu(IV) is reduced to Pu(III) by hydroxylamine nitrate (HAN), and Pu(III) is stripped in a pulsed stripping column. Hydrazine nitrate is introduced to prevent parasitic reoxidation of Pu(III) back to Pu(IV). The stripped plutonium is washed with diluent in a pulsed diluent washing column prior to the final valence adjustment. Unstripped plutonium is extracted in the plutonium barrier mixer-settler bank. Hydroxylamine and hydrazine nitrates are introduced in the last stage of the plutonium barrier. The solvent from the plutonium barrier flows to the uranium-stripping mixer-settler bank.

Uranium is stripped in a slightly acidic 0.02N HNO_3 solution in a uranium-stripping, mixer-settler bank. The stripped uranium stream is washed with diluent in a three-stage, diluent-washing, mixer-settler bank. The stripped solvent from the uranium-stripping mixer-settler is directed to the Solvent Recovery Cycle. The aqueous phase from the uranium diluent washing is directed to the Liquid Waste Reception Unit.

The final valence adjustment of Pu(III) to Pu(IV) is achieved by oxidizing the Pu(III) solution with nitrous fumes. In this process, excess HAN and hydrazine are eliminated, and air stripping of the plutonium solution in an air-stripping column destroys the nitrous acid. The plutonium nitrate solution is received in the plutonium reception tank from where it is transferred to the batch constitution tanks of the Oxalic Precipitation and Oxidation Unit.

The selected aqueous-to-organic ratios in the plutonium extraction and plutonium stripping operations enable the process to obtain a plutonium concentration close to 40 g/L at the outlet of the Purification Cycle.

11.3.2.3.3 Process Chemistry

The extraction process does not involve specific process chemistry. Only the reduction processes for Pu(IV) to Pu(III) by HAN (Equations 11.3-7 and 11.3-8) and hydrazine (Equation 11.3-9) and the parasitic reoxidation of Pu(III) to Pu(IV) (Equation 11.3-10) involve specific chemical reactions.

Plutonium reduction by HAN:

$$2N\,H_3OH^+ + 4\,Pu^{+4} \Rightarrow 4\,Pu^{+3} + N_2O_{(g)} + H_2O + 6\,H^+ \qquad (11.3\text{-}7)$$

$$2N\,H_3OH^+ + 2\,Pu^{+4} \Rightarrow 2\,Pu^{+3} + N_{2(g)} + 2\,H_2O + 4\,H^+ \qquad (11.3\text{-}8)$$

Plutonium reduction by hydrazine:

$$4\,Pu^{4+} + N_2H_5^+ \xrightarrow{H_2O} 4\,Pu^{3+} + N_2O + 5\,H^+ \qquad (11.3\text{-}9)$$

Parasitic reoxidation of Pu(III) to Pu(IV):

$$2\,Pu^{3+} + 2\,HNO_2 + 3\,H^+ + NO_3^- \Rightarrow 2\,Pu^{4+} + 3\,HNO_2 + H_2 \qquad (11.3\text{-}10)$$

11.3.2.3.4 Process Equipment

Figures 11.3-6 and 11.3-7 provide simplified drawings of the Purification Cycle and a pulsed column, respectively.

11.3.2.3.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-4 and 11.3-5, respectively.

11.3.2.3.6 Chemical Process Ranges

The Purification Cycle operates continuously. The feeding solutions from the Dissolution Unit are received in batches. This cycle is designed to process 13.8 kg/day of plutonium. The operating range of the Purification Cycle is 11 to 19 kg/hr of plutonium. The main flows of the Purification Cycle are provided in Table 11.3-6.

11.3.2.3.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.3.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.4 Solvent Recovery Cycle

11.3.2.4.1 Function

The functions of the Solvent Recovery Cycle are as follows:

- Recover the used solvent from the Purification Cycle to prevent the accumulation of degradation products
- Renew the solvent and adjust its TBP content
- Store the treated solvent and continuously feed the Purification Cycle
- Perform a diluent wash operation on the aqueous effluents produced by this operation to remove traces of entrained solvent. (Note: *effluent* in this section refers to effluent from individual process units to other process units; the MFFF discharges no radioactive liquid effluent to the environment.)

11.3.2.4.2 Description

The Solvent Recovery Cycle operates continuously in conjunction with the Purification Cycle. The unit is designed to treat solvents at a nominal flow rate of 4.6 gal/hr (17 L/hr), which corresponds to 14.4 kg/day of plutonium in the Purification Cycle.

The washed solvent is collected in a buffer tank where it is cooled. The Purification Cycle is continuously fed at a controlled flow rate using a dosing pump. The excess solvent, generated by the diluent wash and the content adjustment TBP wash, is transferred to the Liquid Waste Reception Unit. The aqueous effluents generated by washing undergo a diluent wash in a mixer-settler battery (one stage) at ambient temperature to remove traces of entrained solvent. The aqueous-to-organic phase ratio for this operation is around 100:1.

The diluent is recycled in the mixer-settler with a specific system including an airlift and two pots. The recycling flow rate equals the incoming aqueous flow rate from mixer-settler bank 1000. The aqueous-to-organic ratio is close to 1 when recycling is operated.

11.3.2.4.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.4.4 Process Equipment

Figures 11.3-8 and 11.3-9 provide simplified drawings of the Solvent Recovery Cycle and a mixer-settler, respectively.

11.3.2.4.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-7 and 11.3-8, respectively.

11.3.2.4.6 Chemical Process Ranges

The Solvent Recovery Cycle operates continuously in conjunction with the Purification Cycle. The unit is designed to treat solvents at a flow rate of 4.5 gal/hr (17 L/hr), which corresponds to 13.8 kg/day of plutonium. The main flows of the Solvent Recovery Cycle are provided in Table 11.3-9.

11.3.2.4.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.4.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA

11.3.2.5 Oxalic Precipitation and Oxidation Unit

11.3.2.5.1 Function

The functions of Oxalic Precipitation and Oxidation Unit are as follows:

- Receive purified plutonium nitrate concentrated to approximately 40 g/L (maximum is 45 g/L) from the Purification Cycle and prepare uniform batches
- Precipitate out the plutonium nitrate as oxalate
- Produce PuO_2 after filtering, drying, and calcining the oxalate. The filtering operation includes drawing off the mother liquors, washing, and dewatering the plutonium oxalate cake
- Transfer the PuO_2 to the Homogenization Unit, and transfer the mother liquors and the filter washing solutions to the Oxalic Mother Liquor Recovery Unit.

11.3.2.5.2 Description

The conversion line is rated for the processing of 25.2 kg/day of plutonium. Plutonium nitrate solutions arrive from the Purification Cycle where acidity and valency are adjusted. They are received in alternate batches in annular tanks 1000 and 2000 to form a batch with a volume of 21.2 ft^3 (0.6 m^3).

Conversion Feed

Solution from tanks 1000 and 2000 is transferred by a pump to two dosing wheels, which supply one precipitator each. The solutions flow by gravity from the dosing wheels to the precipitators.

Precipitation

Precipitation takes place in two precipitators (5000/6000), which are connected in parallel. The reagents are injected into each precipitator. The plutonium oxalate precipitate carried by the mother liquors escapes via the precipitator overflows and flows by gravity to filter 7000.

Filtration

The extraction screw is driven by one gear motor, and the rotating plate is driven by another. Rotation ensures that the following functions are continuously performed:

- Supply of the filter with mother liquors containing plutonium oxalate
- Dewatering:
- Removal of the cake, plate by plate, by a scraper, and removal by a screw: the removed cake falls into a chute and enters the furnace by gravity.

Drying and Calcination

The furnace consists of two main parts: a drying zone where the plutonium oxalate is dried, and a calcining zone where the oxalate is transformed into PuO_2 in an oxidizing atmosphere of oxygen.

The furnace is heated by resistors in the drying zone and the calcining zone. Thermocouples are used to measure the temperature profile in the furnace. The temperatures of the drying and calcining zones are regulated independently. The speed of rotation of the screw is adjusted manually to maintain the required residence time in the calcining zone. Gas (air, steam, CO_2, and O_2) is extracted after filtration by a fan, which is part of the Offgas Treatment Unit ventilation (see Section 11.3.2.11).

Oxalic Mother Liquor Circuit

The oxalic mother liquors, which are collected in separator pots, flow by gravity to the Oxalic Mother Liquor Recovery Unit. The filtered mother liquors are adjusted to approximately 3.3N with recovered 13.6N acid to avoid any risk of precipitation of plutonium oxalate caused by residual oxalic acid.

Evacuation of Filter

Furnace Offgas System

The gases produced during drying and calcination of the plutonium oxalate (CO_2 and steam), the excess of oxygen, and the air from upstream and downstream of the process are removed by a

negative-pressure circuit comprising a filter, a condenser, a demister, an electric heater, two HEPA filters, and two fans. Gas is extracted from the drying section of the furnace.

11.3.2.5.3 Process Chemistry

The precipitation reaction is as follows:

$$2H_2C_2O_4 + Pu(NO_3)_4 \rightarrow Pu(C_2O_4)_2 + 4\ HNO_3 \qquad (11.3\text{-}11)$$

Plutonium oxalate is transformed into PuO_2 in the calciner according to the following reaction:

$$Pu(C_2O_4)_2 + O_2 \rightarrow PuO_2 + 4\ CO_2 \qquad (11.3\text{-}12)$$

11.3.2.5.4 Process Equipment

Figures 11.3-10 through 11.3-13 provide simplified diagrams of the Oxalic Precipitation and Oxidation Unit, a precipitator, a filter, and a furnace, respectively.

11.3.2.5.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-10 and 11.3-11, respectively.

11.3.2.5.6 Chemical Process Ranges

Oxalic precipitation and oxidation equipment is designed to polish 1 kg/hr of plutonium (i.e., 24 kg/day of plutonium). The operating range of the Oxalic Precipitation and Oxidation Unit is 0 to 1.25 kg/hr of plutonium. The main flows of the Oxalic Precipitation and Oxidation Unit are provided in Table 11.3-12.

11.3.2.5.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.5.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.6 Homogenization Unit

11.3.2.6.1 Function

The functions of the Homogenization Unit are as follows:

- Receive and homogenize the PuO_2 produced in the Oxalic Precipitation and Oxidation Unit
- Fill cans with PuO_2 in such a manner that the mass of plutonium per can is constant
- Prepare samples for laboratory analysis to characterize the batch

- Perform sample-based residual moisture measurement
- Perform thermogravimetry analysis
- Store reference samples.

11.3.2.6.2 Description

The unit is designed for flows corresponding to 25.2 kg/day of plutonium. The PuO_2 produced in the Oxalic Precipitation and Oxidation Unit is continuously fed by gravity from the calcination furnace into one of the two separating hoppers installed in parallel. These hoppers are stirred and weighed. One hopper is filled while the other is mixed or emptied.

The latter packs the oxide in individual recyclable stainless steel cans. The plutonium balance is determined by weighing of the filled cans (Canning Unit) and by determination of the plutonium content of the hopper by powder sampling. Sampling ensures that all the finished product specifications are met in each batch of PuO_2 in each hopper and checks the isotopic composition of the PuO_2 for the finished product of each batch in each hopper.

Each sample is divided in a special fractionation glovebox at the boundary of the Homogenization Unit for the purposes of the laboratory. Reference samples are kept in an archiving can in the Homogenization Unit.

11.3.2.6.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.6.4 Process Equipment

Figures 11.3-14 and 11.3-15 provide simplified diagrams of the Homogenization Unit and a separating hopper, respectively.

11.3.2.6.5 Chemical Process Inventories

The normal inventory of radionuclides involved in this unit is provided in Table 11.3-13.

11.3.2.6.6 Chemical Process Ranges

The Homogenization Unit operates continuously. Each separating hopper has a maximum useful capacity of about 20 kg of PuO_2. In nominal operating process conditions, the plutonium mass inlet flow is approximately 1.05 kg/hr of plutonium, which corresponds to 1.2 kg/hr of PuO_2. The average output is approximately 50 cans of PuO_2 per week, each containing 2.4 kg of PuO_2.

11.3.2.6.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.6.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.7 Canning Unit

11.3.2.7.1 Function

The Canning Unit is designed to package PuO_2 powder in reusable stainless steel cans and transfer them one by one to the MP PuO_2 Buffer Storage Unit to prepare the MOX powder. It is also used to establish the PuO_2 powder material balance.

11.3.2.7.2 Description

The nominal capacity is about 10 cans of PuO_2 per day, each filled with approximately 5.3 lb (2.4 kg) of PuO_2. The PuO_2 powder is gravity-fed from the homogenizer at a temperature not exceeding 302°F (150°C). Full PuO_2 cans are transferred pneumatically in a shuttle to the MP PuO_2 Buffer Storage Unit. Cans that are discarded due to overfilling (as indicated by weighing) or unsatisfactory laboratory results are transferred to the appropriate upstream process.

11.3.2.7.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.7.4 Process Equipment

Figure 11.3-16 provides a simplified drawing of the Canning Unit.

11.3.2.7.5 Chemical Process Inventories

The normal inventory of radionuclides involved in this unit is provided in Table 11.3-14.

11.3.2.7.6 Chemical Process Ranges

The nominal flow rates are as follows:

- PuO_2 inlet from the Homogenization Unit: 1.2 kg/hr
- PuO_2 outlet: approximately 10 full reusable cans per day.

11.3.2.7.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.7.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.8 Oxalic Mother Liquor Recovery Unit

11.3.2.8.1 Function

The functions of Oxalic Mother Liquor Recovery Unit are as follows:

- Continuously receive oxalic mother liquors adjusted to 3.3N with nitric acid from the Oxalic Precipitation and Oxidation Unit
- Continuously receive ventilation effluent droplets from the oxidation and degassing columns
- Concentrate the oxalic mother liquors in a subcritical evaporator to destroy the oxalic ions and to purify the plutonium distillates
- Check and then transfer the distillates to the Acid Recovery Unit
- Monitor and recycle, at a controlled rate, the concentrates at the top of the Purification Cycle.

11.3.2.8.2 Description

The nominal capacity corresponds to processing of the flows generated by precipitation of 24 kg/day of plutonium. The Oxalic Mother Liquor Recovery Unit operates continuously, unlike the Oxalic Precipitation and Oxidation Unit where the oxalic mother liquors are produced. Buffer tanks with more than three days' capacity allow independent operation of the Oxalic Precipitation and Oxidation Unit and the Oxalic Mother Liquor Recovery Unit. The mother liquor solution flows by gravity from the Oxalic Precipitation and Oxidation Unit and Offgas Treatment Unit into feed tank 1000 (volume is 35.3 ft^3 [1 m^3]). After sampling for plutonium concentration, the solution is transferred into feed tank 2000 (volume is 35.3 ft^3 [1 m^3]) by an airlift. The contents of tank 1000 can be transferred by siphon into buffer tank 1500 (capacity is 35.3 ft^3 [1 m^3]). Tanks 1000, 1500, and 2000 are geometrically safe (annular). From tank 2000, the solution passes through a double airlift and supplies evaporator 3000.

Concentration of Mother Liquors and Destruction of Oxalic Ions

Processing of Distillates

The distillates from the column of evaporator 3000 are condensed and cooled. The distillates supply the X-ray fluorescence at a regulated rate. This analyzer monitors the plutonium concentration of the distillates online. The distillates are then either channeled to the Acid Recovery Unit if the plutonium concentration is correct or recycled to tank 1500 in the unit if this is not the case. A pot also supplies the distillate reflux system at the top of evaporator 3000 at a regulated rate.

Processing of Concentrates

The concentrates are drawn off at the foot of evaporator 3000 by an airlift and gravity-fed into concentrate reception tank 4000 (volume is 26.4 gal [100 L]). The concentrates are drawn off discontinuously depending on the desired flow rates of the unit.

The solution is transferred by siphon into concentrate control tank 4100 (volume is 26.4 gal [100 L]). When tank 4100 is full and the oxalate concentration meets requirements, its contents are transferred into tank 4200 (volume is 26.5 gal [100 L]) by siphon. Tank 4200 distributes the concentrates to the Purification Cycle by an airlift.

11.3.2.8.3 Process Chemistry

Plutonium oxalate is converted to plutonium nitrate and oxalic acid. This latter decomposes itself into H_2O, CO_2, and NO_2:

$$Pu(C_2O_4)_2 + 4\ HNO_3 \xrightarrow{Mn^{2+}} Pu(NO_3)_4 + 2\ H_2C_2O_4 \qquad (11.3\text{-}13)$$

$$H_2C_2O_4 + 2\ HNO_3 \xrightarrow{Mn^{2+}} 2\ CO_2 + 2\ NO_2 + 2\ H_2O \qquad (11.3\text{-}14)$$

These reactions are catalyzed by Mn^{2+} ions.

Since Pu nitrate undergoes prolonged boiling and considering the high acidity of the medium, Pu(IV) nitrate is oxidized and gives Pu(VI) nitrate as the following reaction :

$$3\ Pu(IV) + 2\ H_2O \xrightarrow{Mn^{2+}} 2\ Pu(III) + PuO_2 + 4\ H^+ \qquad (11.3\text{-}15)$$

The medium being highly acid, Pu(III) is itself oxidized into Pu(IV).

Therefore, at the end of the evaporator, the concentrates contain Pu at valency VI as $PuO_2(NO_3)_2$.

11.3.2.8.4 Process Equipment

Figures 11.3-17 and 11.3-18 provide simplified drawings of the Oxalic Mother Liquor Recovery Unit and an evaporator, respectively.

11.3.2.8.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-15 and 11.3-16, respectively.

11.3.2.8.6 Chemical Process Ranges

This unit is designed to accommodate a flow rate of 250 gal/hr (66 L/hr) of oxalic mother liquors. The main flows of this unit are provided in Table 11.3-17.

11.3.2.8.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.8.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.9 Acid Recovery Unit

11.3.2.9.1 Function

The functions of the Acid Recovery Unit are as follows:

- Receive extraction raffinates from the Purification Cycle in batches, and continuously receive oxalic mother liquor distillates from the Oxalic Mother Liquor Recovery Unit and active liquid effluents from the Offgas Treatment Unit equipment ventilation
- Concentrate most of the radioactivity contained in the effluents and send it to the Silver Recovery Unit
- Recover concentrated acid for recycling in the process
- Recover distillates from the rectification column.

11.3.2.9.2 Description

The nominal capacity corresponds to processing the flows generated by purification of 88.3 ft^3/day (2.5 m^3/day) of liquor. The system is designed to accommodate a nitric acid flow rate of 40.7 gal/hr (154 L/hr). The 88.3-ft^3 (2.5-m^3) feed tank (1000) receives the following:

- Raffinates from the Purification Cycle in batches of 53 ft^3 (1.5 m^3)
- Oxalic mother liquor distillates (Oxalic Mother Liquor Recovery Unit evaporator 3000) continuously
- Recombined acid from the Offgas Treatment Unit
- Effluents from laboratories in batches.

Evaporator 2000

The solution is transferred from the feed tank by double-stage air and is transferred to the boiler of evaporator 2000. The boiler of evaporator 2000 is of the natural recirculation thermosiphon type. The heating power is kept constant by regulating the pressure in the boiler. The level of liquid in the separator of evaporator 2000 regulates the feed rate of the airlift. The mixture of liquid and steam produced at the top of the evaporator is separated in the separator of evaporator 2000. The concentrates from evaporator 2000 are drained off discontinuously several times a day at a constant rate by airlift. The concentrates flow into concentrate tank 3000. From this 52.8-gal (200-L) tank, the concentrates are sent by jet to the Silver Recovery Unit (tank 1000). The steam distillates are condensed in condenser 2200. The condensates are fed to evaporator 6000.

Evaporator 6000

The condensed distillates from evaporator 2000 flow to the bottom of evaporator 6000. The boiler of evaporator 6000 is of the natural recirculation thermosiphon type. The level of liquid in the separator of evaporator 6000 regulates heating. The mixture of liquid and steam produced at the top of the evaporator is separated in the separator of evaporator 6000. The concentrates from evaporator 6000 are drained off discontinuously several times a day at a constant rate by airlift. The concentrates flow back by gravity into feed tank 1000.

Rectification Column (Evaporator 2500)

At the outlet of the separator of evaporator 6000, the distillates enter rectification column 2500. This equipment consists of a rectification column and a boiler. The rectification column has capped trays. The boiler is of the natural recirculation thermosiphon type. A reflux system at the top of the column can be used to spray the upper trays and improve decontamination. The level in the separator of the rectification column regulates heating. The recovered acid is drawn off by airlift and cooled. The acid draw-off flow rate is regulated to maintain the desired acidity. The acid is received in recovered acid feed tank 4000 (volume is 132 gal [500 L]). The recovered acid is continuously transferred by pump into a reagents pot for AP recovered nitric acid solution. The excess acid recovered is drained by pump into buffer tank 4500 (volume is 132 gal [500 L]). In tank 4500, the solution is analyzed and temporarily stored before being transferred by pump to the Liquid Waste Reception Unit.

At the rectification column outlet, the vapors are condensed in condenser 2800, and then the condensates flow into the pot. From this pot, the reflux system of the rectification column is regulated. The distillates are cooled in cooler 2900 and flow by gravity into distillate tank 5000 (volume is 177 ft^3 [5 m^3]). The distillate is continuously transferred by pump into the pot for AP water recycle solution feeding. The excess recycle water is drained in batches by pump into buffer tank 5500 (volume is 177 ft^3 [5 m^3]). The excess recycle water is analyzed and temporarily stored before being transferred by pump to the Liquid Waste Reception Unit.

11.3.2.9.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.9.4 Process Equipment

Figure 11.3-19 provides a simplified drawing of the Acid Recovery Unit.

11.3.2.9.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-18 and 11.3-19, respectively.

11.3.2.9.6 Chemical Process Ranges

The Acid Recovery Unit operates continuously. This unit is designed to accommodate a nitric acid flow rate of 40.7 gal/hr (154 L/hr). The main flows of this unit are provided in Table 11.3-20.

11.3.2.9.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.9.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.10 Silver Recovery Unit

11.3.2.10.1 Function

The Silver Recovery Unit uses electrodeposition to recover silver from the first stage of the Acid Recovery Unit and recycle it into the Dissolution Unit. The main functions of the Silver Recovery Unit are as follows:

- Receive concentrates from the Acid Recovery Unit and deposit the silver they contain on the electrolyzer cathodes
- Dissolve the silver deposit in recycled nitric acid
-
- Analyze the silver concentration of the resulting solution and adjust it if necessary
- Recycle the recovered silver nitrate to the Dissolution Unit.

11.3.2.10.2 Description

The Silver Recovery Unit can be operated either in the manual or the automatic mode.

For an electrolyzer batch, a pump recirculates the liquid and ensures renewal of the solution between the electrolyzer and buffer tank 1000 (53 ft^3 [1.5 m^3]). This tank is made of 304L stainless steel.

Control Tank 3000

This 52.8-gal (200-L) 304L stainless steel tank receives a first batch of silver dissolved in recycled nitric acid and stores the solution while another batch is being processed. The solution is then recycled to the electrolyzer for the silver deposit to be dissolved again with the second batch and returns to the control tank. A pump circulates the solution between the control tank and the electrolyzer while the silver deposit is being dissolved again.

The control tank features a sampling airlift to analyze and adjust, as necessary, the silver content before transfer to buffer tank 4000.

Buffer Tank 4000

This 52.8-gal (200-L) 304L stainless steel buffer tank features an overflow and stores recovered silver nitrate before transferring it to the Dissolution Unit by dosing pump.

11.3.2.10.3 Process Chemistry

$$NO_3^- + 2e^- + 3H^+ + H_2O_2 \Rightarrow \frac{1}{2} N_2O + \frac{5}{2} H_2O + O_2 \qquad (11.3\text{-}25)$$

11.3.2.10.4 Process Equipment

Figure 11.3-20 provides a simplified drawing of the Silver Recovery Unit.

11.3.2.10.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-21 and 11.3-22, respectively.

11.3.2.10.6 Chemical Process Ranges

The Silver Recovery Unit is operated in batches. The Silver Recovery Unit is designed to operate 5 kg of silver in one batch. The operating range of this unit is 0 to 84 m^3/hr. The main process flow rates are as follows:

- Tank 1000 / electrolyzer 2000 recirculation flow rate: approximately 424 ft^3/hr (12 m^3/hr)
- Tank 4000 / electrolyzer 2000 recirculation flow rate: approximately 53 gal/hr (200 L/hr).

11.3.2.10.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.10.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.11 Offgas Treatment Unit

11.3.2.11.1 Function

The Offgas Treatment Unit ventilation system is dedicated to process equipment. The functions of this unit are as follows:

- Remove plutonium from offgases collected from the Dissolution Unit and from the oxidation and degassing columns (Purification Cycle)
- Recombine the nitrous fumes in a specific NO_x scrubbing column
- Clean, by water scrubbing, the offgases collected from all the AP units
- Treat the offgas flow by HEPA filtration before release to the stack
- Maintain negative pressure in the tanks and equipment connected to the process ventilation system.

A specific Offgas Treatment Unit extraction system is dedicated to the pulsed purification columns, with similar functions:

- Treat offgases by HEPA filtration before release to the stack
- Maintain negative pressure in the pulsation system and the pulsed columns legs.

11.3.2.11.2 Description

Offgases from Dissolution and Oxidation and Degassing Columns

The NO_x-containing offgases are gathered downstream of a cap impactor to remove droplets. The effluent stream collected is recycled, by gravity, to reception tank 1000 in the Oxalic Mother Liquor Recovery Unit. Then offgases are routed to recombination column 1000 where they are scrubbed with recycled effluents and with recovered distillates from the Acid Recovery Unit. Negative pressure in column 1000 is maintained constant. The column is fitted with capped trays and a buffer tank with a cooling coil. Column 1000 is sprayed at a high rate by recycling effluents from the buffer tank using an airlift. The offgases then pass through a demister. Column 1000 offgases are extracted by an air ejector. The extraction rate is regulated from pressure indication at the top of the column.

Process Equipment Offgases

Column 2000 receives the ventilation gases and those from recombination column 1000. Negative pressure in column 2000 is maintained constant. The gases are scrubbed with recycled effluents and then with water. The column is fitted with capped trays and a buffer tank with a cooling coil. Column 2000 recycles effluents from the buffer tank using an airlift. The washed gases successively pass through a cooler, a demister, an electric heater, a filtering line, and an exhauster before being released through the stack.

Pulsed Purification Columns Extraction System

The pulsation air from columns legs is routed to the extraction line. The air successively passes through an electric heater, a filtering line, and an exhauster before being released through the stack.

11.3.2.11.3 Process Chemistry

This section is not applicable to this unit.

11.3.2.11.4 Process Equipment

Figure 11.3-21 provides a simplified drawing of the Offgas Treatment Unit.

11.3.2.11.5 Chemical Process Inventories

The normal inventories of radionuclides and chemicals involved in this unit are provided in Tables 11.3-23 and 11.3-24, respectively.

11.3.2.11.6 Chemical Process Ranges

The Offgas Treatment Unit operates continuously. The NO_x scrubbing column is designed to treat approximately 15N to 30N m^3/hr. The designed capacity of the column pulsation air extraction is 150N m^3/hr. The main ventilation line (offgas scrubbing and filters) is designed to

process approximately 250N to 400N m^3/hr. The main flows of this unit are provided in Table 11.3-25.

11.3.2.11.7 Chemical Process Limits

Normal operating parameters are described in Section 11.3.2.11.6. Principal SSCs are described in Chapter 5. Specific operating limits and the associated IROFS will be provided in the ISA.

11.3.2.12 Liquid Waste Reception Unit

The Liquid Waste Reception Unit will receive liquid waste from the AP process for temporary storage before sending it to SRS for treatment and processing.

11.3.2.13 Sampling System

This section describes the principles of liquid sampling and basic equipment design for the AP process. The sampling system is applicable for radioactive and chemical solutions. Three liquid sampling system principles that will be used at the MFFF are direct, suction, and remote sampling. In direct sampling, the solution is directly extracted from the process equipment by gravity flow or with a recycling pump into a vial. Direct sampling is limited to non-aggressive reagents or effluents of suspect origin. A large sample volume provides a lower detection limit. In suction sampling, a vial is filled by suction through a needle by the vacuum in the vial. Suction filling can be performed manually or with a moving cask. Aggressive reagents can be sampled manually but with vacuum vial filling. Pluggage of the sampling system is not expected because all AP process solutions are clear (without particles). A moving cask is used for suction filling of active liquids. With remote sampling, the solution is lifted up by an airlift head from which direct vacuum sampling is carried out. For concentrated radioactive liquid waste, remote sampling under a box is required. Table 11.3-26 summarizes the sampling systems. All sampling systems will be qualified using engineering studies and/or evaluations.

11.3.3 Major Components

The major components of each unit or system are described in Section 11.3.2.

11.3.4 Control Concepts

The control concepts used in the AP process are based on existing control principles of COGEMA'S URP and Plutonium Finishing Facility at La Hague in France. The AP 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 AP process controls are composed of the 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 and that undesired operational conditions or events will not occur or will be mitigated. Section 11.6 discusses the MFFF I&C systems in more detail.

In general, each unit is controlled by one or several programmable logic controllers (PLCs) associated with a monitoring workstation located in the AP control room. All units are operated in an automatic mode. 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 Manufacturing Management Information System (MMIS) collects the information coming from all process units to control the position and the exchange of special nuclear material (SNM) as well as the traceability and the quality of the products.

11.3.5 System Interfaces

The system interfaces of each unit or system are described in Section 11.3.2.

11.3.6 Design Basis for Non-Principal SSCs

The design of the AP process is as similar as practical to the proven design currently employed at La Hague's Plutonium Finishing Facilities. Departures from the La Hague design result from United States regulatory requirements, lessons learned at La Hague, or manufacturing and throughput requirements specific to the MFFF. The AP process is designed to receive weapons-grade plutonium from the PDCF and to remove the impurities from the feed plutonium from the PDCF for use in the MP process. The plutonium isotopic composition is as follows:

- $^{236}Pu < 1$ ppb, at the origin of pit
- $^{238}Pu < 0.05\%$
- $90\% < {}^{239}Pu < 95\%$
- $5\% < {}^{240}Pu < 9\%$
- $^{241}Pu < 1\%$ during lifetime of plant
- $^{242}Pu < 0.1\%$.

The feed chemical impurities are listed in Table 11.3-27, and the radionuclide impurities are listed in Table 11.3-28. In addition, the americium content is as follows:

$$\frac{^{241}Am}{Pu\ total + {}^{241}Am} < 0.7\% \text{ during the lifetime of the plant}$$

The feed PuO_2 powder has a maximum density of less than 7 g/cc (nominal density of 4.5 g/cc), a moisture content of less than 0.5% (reabsorption capability of less than 3%), and a maximum particle size of less than 200 μm (minimum particle size greater than 5 μm).

The reagents are listed below:

Liquid Reagents

- Nitric acid (13.6N)
- Hydrogen peroxide

- Tributyl phosphate (TBP) (solvent)
- Hydrogenated tretrapropylene (branched dodecane, TPH) (diluent)
- Demineralized water
- Hydroxylamine nitrate (HAN)
- Hydrazine hydrate
- Sodium hydroxide (NaOH).

<u>Gas</u>

- Liquefied nitrogen tetroxide
- Oxygen
- Nitrogen.

<u>Solids</u>

- Silver nitrate ($Ag NO_3$)
- Manganese nitrate ($Mn (NO_3)_2$
- Sodium carbonate ($Na_2 CO_3$)
- Oxalic acid ($H_2C_2O_4$).

Intermediate products are as follows:

- Dissolution liquors exiting the dissolution step
- Loaded solvent after the extraction step
- Plutonium nitrate exiting the purification step
- Plutonium oxalate after precipitation and filtration.

The composition and physical properties of the polished (output) plutonium are discussed in Section 11.2.6.

The AP 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 can opening is performed in the MP Area; inner can and convenience can opening is performed in the AP Area.
- 3013 convenience cans are transferred to the AP area by pneumatic transfer.

[ ]

11.3.7 Design Basis for Principal SSCs

The design basis for principal SSCs associated with the AP Process is included and discussed with other systems.

Tables

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Table 11.3-1. Inventory of Radionuclides for the Decanning Unit

Table 11.3-2. Inventory of Radionuclides for the Dissolution Unit

Table 11.3-3. Inventory of Chemicals for the Dissolution Unit

Table 11.3-4. Inventory of Radionuclides for the Purification Cycle

Table 11.3-5. Inventory of Chemicals for the Purification Cycle

Table 11.3-6. Process Flows – Purification Cycle

Table 11.3-7. Inventory of Radionuclides for the Solvent Recovery Cycle

Table 11.3-8. Inventory of Chemicals for the Solvent Recovery Cycle

Table 11.3-9. Process Flows – Solvent Recovery Cycle

Table 11.3-10. Inventory of Radionuclides for the Oxalic Precipitation and Oxidation Unit

Table 11.3-11. Inventory of Chemicals for the Oxalic Precipitation and Oxidation Unit

Table 11.3-12. Process Flows – Oxalic Precipitation and Oxidation Unit

Table 11.3-13. Inventory of Radionuclides for the Homogenization Unit

Table 11.3-14. Inventory of Radionuclides for the Canning Unit

Table 11.3-15. Inventory of Radionuclides for the Oxalic Mother Liquor Recovery Unit

Table 11.3-16. Inventory of Chemicals for the Oxalic Mother Liquor Recovery Unit

Table 11.3-17. Process Flows – Oxalic Mother Liquor Recovery Unit

Table 11.3-18. Inventory of Radionuclides for the Acid Recovery Unit

Table 11.3-19. Inventory of Chemicals for the Acid Recovery Unit

Table 11.3-20. Process Flows – Acid Recovery Unit

Table 11.3-21. Inventory of Radionuclides for the Silver Recovery Unit

Table 11.3-22. Inventory of Chemicals for the Silver Recovery Unit

Table 11.3-23. Inventory of Radionuclides for the Offgas Treatment Unit

Table 11.3-24. Inventory of Chemicals for the Offgas Treatment Unit

Table 11.3-25. Process Flows – Offgas Treatment Unit

Table 11.3-26. Sampling System Classification

Table 11.3-27. Chemical Impurities of Plutonium Oxide Feed Material

Chemical Component	Maximum Content (µg/g Pu)	Maximum Exceptional Content (µg/g Pu)	Chemical Component	Maximum Content (µg/g Pu)	Maximum Exceptional Content (µg/g Pu)
Ag	NA	10,000	Nb	100	10,000
Al	150	10,000	Ni	200	10,000
B	100	1,000	P	200	1,000
Be	100	10,000	Pb	200	1,000
Bi	100	1,000	S	250	1,000
C	500	1,500	Si	200	200
Ca	500	10,000	Sm	2	1,000
Cd	10	1,000	Sn	100	10,000
Cl	(+ F < 250)	500	Ti	100	10,000
Co	100	10,000	Th	100	100
Cr	100	250	V	300	10,000
Cu	100	500	W	200	10,000
Dy	1	1,000	Zn	100	1,000
Eu	1	1,000	Zr	50	1,000
F	(+ Cl < 250)	350	Boron Equivalent	Not applicable	
Fe	500	1,000	Total Impurities	18,800	
Ga	12.000	12,500			
Gd	3	1,000			
In	20	1,000			
K	150	10,000			
Li	400	10,000			
Mg	500	10,000			
Mn	100	10,000			
Mo	100	1,000			
N	400	400			
Na	300	10,000			

Table 11.3-28. Radionuclide Impurities of Plutonium Oxide Feed Material

Impurity	Isotope	Maximum content µg/g Pu
Americium	^{241}Am: 100 %	7,000 µg/g Pu
Uranium	^{235}U: 93.2 %	Standard value: 5,000 µg/g Pu Maximum value: 20,000 µg/g Pu for 10 % of the delivered cans during one year Annual maximum value: 17 kg

Figures

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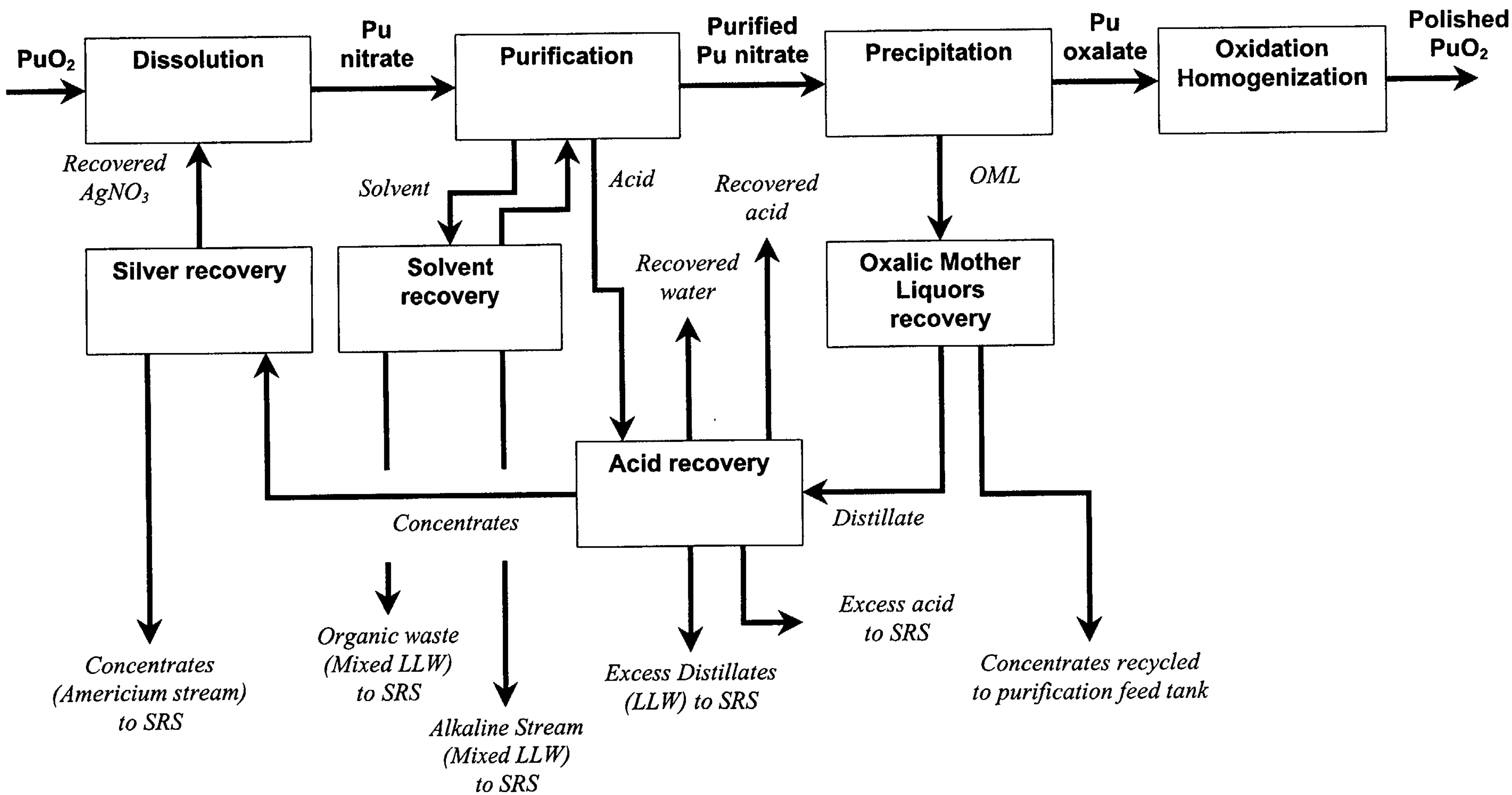

Figure 11.3-1. AP Process Overview

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Figure 11.3-2. General Flow Diagram

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Figure 11.3-3. Schematic of the Decanning Unit

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Figure 11.3-4. Schematic of the Dissolution Unit

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Figure 11.3-4. Schematic of the Dissolution Unit (continued)

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Figure 11.3-5. Drawing of the Electrolyzer

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Figure 11.3-6. Purification Cycle

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Figure 11.3-7. Pulsed Column

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Figure 11.3-7. Pulsed Column (continued)

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Figure 11.3-8. Solvent Recovery Cycle

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Figure 11.3-8. Solvent Recovery Cycle (continued)

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Figure 11.3-9. Mixer-Settler

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Figure 11.3-10. Oxalic Precipitation Unit

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Figure 11.3-10. Oxalic Precipitation Unit (continued)

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Figure 11.3-11. Precipitator

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Figure 11.3-12. Filter

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Figure 11.3-13. Furnace

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Figure 11.3-14. Homogenization Unit

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Figure 11.3-14. Homogenization Unit (continued)

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Figure 11.3-15. Separating Hopper

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Figure 11.3-16. Canning Unit

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Figure 11.3-17. Oxalic Mother Liquor Recovery Unit

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Figure 11.3-17. Oxalic Mother Liquor Recovery Unit (continued)

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Figure 11.3-18. Evaporator

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Figure 11.3-19. Acid Recovery Unit

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Figure 11.3-19. Acid Recovery Unit (continued)

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Figure 11.3-20. Silver Recovery Unit

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Figure 11.3-20. Silver Recovery Unit (continued)

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Figure 11.3-21. Offgas Treatment Unit

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Figure 11.3-21. Offgas Treatment Unit (continued)

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