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High-Level Functional and Operational Requirements for the Advanced Fuel Cycle Facility

Charles V. Park

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High Level Functional & Operational Requirements for the Advanced Fuel Cycle Facility

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ACRONYMS

ABR	Advanced Burner Reactor
AFCF	Advanced Fuel Cycle Facility
ALARA	As low as reasonably achievable
ASME	American Society of Mechanical Engineers
BWR	Boiling Water Reactor
CAS	Central Alarm Station
DBA	design basis accident
DBT	design basis threat
DOE	Department of Energy
DOG	dissolver off-gas
DOT	Department of Transportation
EDA	Extended Detection Area
EPA	Environmental Protection Agency
F&OR	Functional and Operational Requirements
FP	fission product
Gen IV	Generation IV
GNEP	Global Nuclear Energy Partnership
GTCC	Greater Than Class C
GWd	gigaWatt day
HEPA	high efficiency particulate air
HLW	high-level waste
HOG	Hot Off-Gas
HVAC	heating, ventilation and air conditioning
I&C	Instrumentation and Controls
IAEA	International Atomic Energy Agency
LLW	low-level waste
LTA	Lead-Test Assembly
LWR	Light Water Reactor
M&TE	Measuring and Testing Equipment
MAA	Material Access Area

MC&A	Material Control and Accounting
MLLW	mixed low-level waste
MTIHM	Metric Ton Initial Heavy Metal
MWt	Megawatt thermal
NEPA	National Environmental Policy Act
NQA	National Quality Assurance
NRC	Nuclear Regulatory Commission
PA	Protected Area
PF	Protective Force
PR&PP	Proliferation Resistance and Physical Protection
PWR	pressurized water reactor
QA	quality assurance
QC	quality control
R&D	research and development
RCRA	Resource Conservation and Recovery Act
SAMACS	Security Alarm Management and Control Systems
SAR	Safety Analysis Report
SAS	Secondary Alarm Station
SNF	spent nuclear fuel
SNM	special nuclear material
SST	safe, secure transport
TRU	transuranic
US	United States
VOG	vessel off-gas
vppm	vapor parts per million
WAC	Waste Acceptance Criteria
WESF	Waste Encapsulation Storage Facility
WIPP	Waste Isolation Pilot Plant

1. INTRODUCTION

This document describes the principal functional and operational requirements for the proposed Advanced Fuel Cycle Facility (AFCF). The AFCF is intended to be the world's foremost facility for nuclear fuel cycle research, technology development, and demonstration. The facility will also support the near-term mission to develop and demonstrate technology in support of fuel cycle needs identified by industry, and the long-term mission to regain and retain U.S. leadership in fuel cycle operations. The AFCF is essential to demonstrate a more proliferation-resistant fuel cycle and make long-term improvements in fuel cycle effectiveness, performance and economy. The relationship of this Functional and Operational Requirements (F&OR) document to other project documents is shown in Figure 1-1.

The AFCF will be used to develop and demonstrate the nuclear fuel cycle technologies necessary to meet the requirements of a sustainable United States (U.S.) nuclear industry for the next 50 years. The AFCF will comprise the capabilities necessary to develop and test fuel cycle processes and equipment to: (1) separate the constituents of spent nuclear fuels, including recycled fuels, and (2) fabricate advanced proliferation-resistant, recycle fuel types. The mission also includes demonstration of the viability of advanced waste forms and advanced safeguards technologies. The facility will resolve production issues related to process control and integration, reliability, availability and scale-up (via integrated systems operations tests at engineering scale). The facility will also develop, test and demonstrate improved and more effective nuclear material control and accounting (MC&A) techniques.

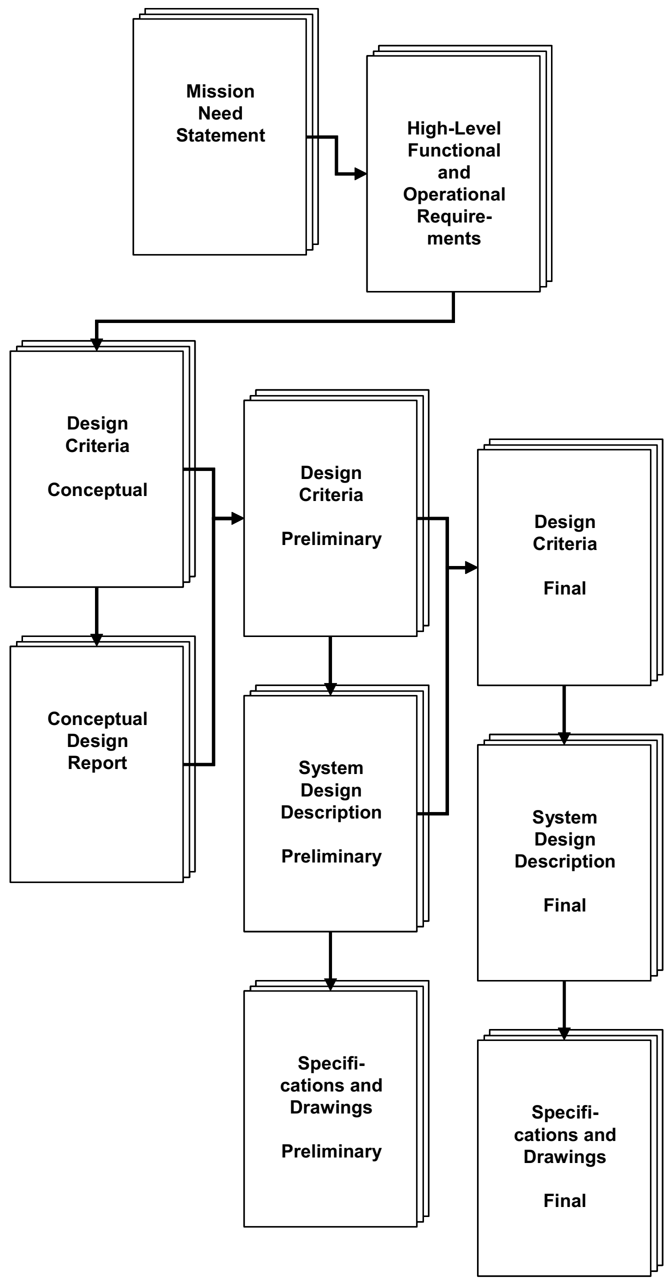

Figure 1-1 Document hierarchy.

2. OVERVIEW

2.1 AFCF Description

The AFCF shall include large shielded and remotely maintained areas to validate, demonstrate, and improve spent fuel treatment processes, fuel fabrication processes, and safeguards monitoring. These systems will be fully integrated and operated at engineering scale. The facility will also include small shielded and remotely maintained areas (e.g., automated and manual hot cells and gloveboxes) to conduct development activities and validate bench-scale unit operations. This development process will provide critical information for the design of future full-scale production facilities and the confidence to know that production-scale processes will perform as intended. In general, bench-scale hot cell or glove box work is performed at kilogram quantities per year, whereas engineering scale is often at one to tens of tons per year, and commercial operations may involve hundreds or thousands of tons per year.

The AFCF shall be designed, constructed and operated with emphasis on protection of public and worker safety and the environment.

2.2 Primary Facility Functions

The primary functions of the AFCF are shown below and summarized in the following sections. See Figure 2-1.

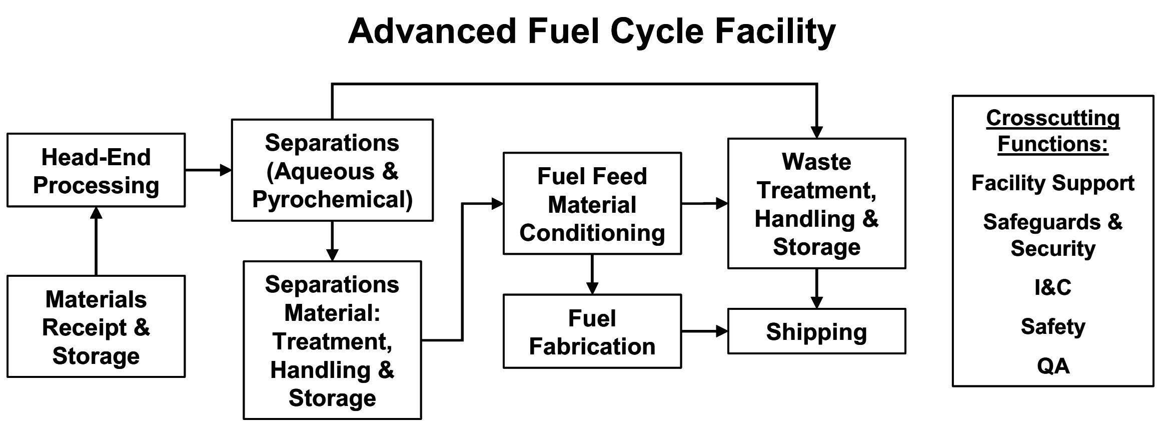

Figure 2-1 AFCF functions.

2.2.1 Materials Receipt and Storage

The AFCF will provide the capability to receive multiple types of nuclear materials (e.g., spent fuel shipments from test reactors, commercial Light Water Reactors (LWR), existing spent nuclear fuel storage facilities, Generation IV (Gen IV) demonstration reactors, and/or fast reactor (FR) recycle fuels and targets). The facility will be capable of receiving either truck or railcar mounted spent fuel shipping containers. The capability to inspect, temporarily store, and move nuclear material to manage the accountability and flow of materials into each head-end preparation process (separations and fuel fabrication) will be provided. Equipment will be provided to remotely handle, monitor, inspect and temporarily store radioactive material in a suitable environment that provides for an adequate level of safety (shielding, confinement, heat removal, monitoring, etc.) and security. Storage systems and handling equipment will be designed to assure safe handling of all nuclear materials. Irradiated materials will be received after undergoing sufficient decay time to allow processing.

2.2.2 Head-End Processing

The AFCF will provide the capability to pre-treat (e.g., disassemble, chop, heat, combust, grind), chemically dissolve and homogenize or electrochemically convert, and provide material accountancy for various kinds of nuclear material and spent fuels.

2.2.3 Separations

Following head-end processing tailored to subsequent steps, the fuel components will be separated using technologies referred to as “aqueous” liquid-based methods and “dry” molten salt pyrochemical methods, or combinations of these. The design of the AFCF will support configuration changes to accommodate the evolution of research and development (R&D) programs that could include these methods and their support systems. Separations processes will include all provisions for timely, safe, and secure operations (e.g., process recycle, criticality control, security, integrated process control, sampling, and MC&A) at the proposed processing rates.

2.2.4 Separations Material Treatment, Handling and Storage

The separations material handling function of the AFCF includes material collection; analysis for criticality control, MC&A, security control, solid product formation, handling, packaging, and interim storage of conditioned and separated materials. The AFCF material packaging function will provide the capability to develop and validate methods to isolate and package various separated materials. These operations will require a variety of processes to be tested, modified, and improved to support optimum production-scale operations. Material storage will provide adequate surge capacity to allow efficient production operations and to provide material when it is needed. Additional temporary storage space will be provided for testing programs that will validate time-related integrity issues for new product forms and/or material package configurations.

2.2.5 Fuel Feed Material Conditioning

The product conditioning function of the AFCF includes material blending operations with liquid and solid physical phases by themselves and in various combinations, fissile content adjustment, analysis for criticality control and MC&A, fuel scrap recovery and chemical or physical conditioning to obtain the desired feed material for fuel fabrication. Some operations may require inert cover gases to obtain the desired product characteristics.

2.2.6 Fuel Fabrication

The AFCF fuel fabrication function will be capable of developing a large variety of advanced fuel types and transmutation targets with various elemental blends and configurations. The facility will provide the capability to remotely manufacture and inspect fuels ranging from test specimens for irradiation to full-size Lead Test Assemblies (LTAs). Packaging and temporary storage of manufactured fuel will be provided in addition to provisions for scrap recycle, criticality control, security, and MC&A.

2.2.7 Waste Treatment, Handling and Storage

The waste handling function includes waste analysis and certification, treatment, packaging, inspection, monitored interim storage, and MC&A. The AFCF will provide the capability to produce new waste forms, and treat, package, and temporarily store all required waste types. Treatment and testing capabilities will be available to develop and demonstrate waste treatment processes and convert waste streams to meet applicable Waste Acceptance Criteria (WAC). Control and testing capabilities will normally assure an acceptable and certified waste package is produced but facilities and flexibility for re-work of off-specification waste forms will be available. Monitoring and storage areas will be provided as required for integrity testing and interim storage observations.

2.2.8 Shipping

The AFCF will provide processes and equipment necessary to support truck and rail transfers to and from, and within the AFCF. These transfers include shipping manufactured fuels and targets, by-products, waste, failed equipment, and other items generated by facility testing, development, and operations. Shipping processes will include provisions for cask loading, industrial and radiological safety, Department of Transportation (DOT) compliance and inspection, criticality control, security, and MC&A.

Cross-cutting Functions Include:

2.2.9 Facility Support

The AFCF will include the necessary support infrastructure and balance of plant support features to accomplish mission objectives. This function includes facility access, control center, bench-scale testing, remote cold mock-up, analytical services, instrumentation and control, storage buildings, training and office facilities, utilities, integration of operations personnel, cold chemical makeup, confinement control, effluent management, support for operational readiness reviews, National Environmental Policy Act (NEPA) support, environmental permitting, and other programmatic needs.

2.2.10 Safeguards and Security

The safeguards and security function will meet all current DOE requirements for the production, storage, and transportation of Category I special nuclear material (SNM), in a manner sufficient to prevent theft, unauthorized use, or radiological sabotage by an adversary force as defined in the current (2005) DOE Design Basis Threat. The facility design will incorporate innovative, state-of-the-art protection system features to ensure adequate protection, mitigate the impact of future changes in the Design Basis Threat, and minimize the number of Protective Force personnel required to achieve a level of protection that is acceptable to the DOE.

MC&A will be based on two levels of requirements. The first level will provide the current safeguards required for licensing, regulating, and/or monitoring the AFCF. The second level will provide the capability to develop advanced safeguards for licensing, regulating, and/or monitoring future full-scale commercial facilities. The AFCF will comply with all Department of Energy (DOE) MC&A requirements. It will also provide the capability to develop and demonstrate advanced compliance methods related to the Nuclear Regulatory Commission (NRC) and International Atomic Energy Agency (IAEA) requirements.

2.2.11 Instrument & Control (I&C) Infrastructure

The I&C infrastructure for the AFCF will include facility-wide data collection, data management, control action, material accountability, human data interface, and modeling systems to support operation and demonstration of R&D prototype experiments and commercial-scale advanced production. The I&C system provides the cross-cutting interconnections and human data interfaces between each of the primary facility functions and allows for their seamless operation at both bench/experimental and engineering scales. This infrastructure will support a flexible, modular, state-of-the-art design for ease of maintenance, reconfiguration, and operation of both experimental and production demonstrations.

2.2.12 Safety

The AFCF Project will comply with Title 10 Code of *Federal Regulations*, Part 830, (Nuclear Safety Management), Subpart B (Safety Basis Requirements), and DOE Order 420.1B (Facility Safety). The project will also comply with all other applicable laws, regulations, DOE Orders, Standards, Guides and applicable national consensus standards related to safety. The project will initiate compliance with the current draft of DOE-STD-1189-2006 (Integration of Safety into the Design Process) during the conceptual design phase, and shall be fully compliant with the requirements contained in the final Standard in accordance with the project compliance plan to be developed and implemented upon approval of the Standard. All Documented Safety Analysis and other safety documentation deliverables will be developed in accordance with requirements contained in DOE Order 413.3 *Project Management* for each phase of the project. The project safety system, structure, and component selection process will be implemented in a manner such that selected controls meet current requirements and are also flexible enough to support changing processes and requirements over the AFCF design lifetime of 50 years.

2.2.13 Quality Assurance

The AFCF Project is required to comply with Title 10 *Code of Federal Regulations*, Part 830, Subpart A and DOE Order 414.1C for Nuclear Facilities and Activities. The use of applicable elements of American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance - 2000 (NQA-1-2000) has been adopted by the Project as the baseline for developing and implementing the AFCF Quality Assurance Program.

2.3 Assumptions

The following assumptions provide the framework for the AFCF functions and requirements.

2.3.1 Programmatic and general facility assumptions

2.3.1.1 The AFCF will be a government-owned and contractor-operated facility. DOE and the host State will provide the necessary regulatory and safety oversight.

2.3.1.2 The AFCF will test and demonstrate the capability to meet NRC licensing (but will not be licensed by the NRC).

2.3.1.3 The AFCF will provide the capability to test for and demonstrate the ability to meet selected IAEA principles.

2.3.1.4 The AFCF, including hot cells, laboratories, services and support functions will be designed for a 50-year operational lifetime but the design lives of individual test equipment and engineering-scale demonstrations may be shorter and will be individually specified according to need.

2.3.1.5 The AFCF will provide the flexibility to support DOE's recycling and remote fuel fabrication technology development and demonstration program needs for a minimum of 50 years. The near-term focus will be on demonstrating engineering-scale operations for the next-generation recycling plants.

2.3.1.6 The AFCF facility will have an initial average annual production availability factor of 67% (i.e., not more than 125 days per year will be planned for demonstration campaign turnaround and facility maintenance).

2.3.1.7 The AFCF will provide a totally integrated stand-alone operational capability. All necessary site infrastructure including office, support, and service buildings are included in the project scope.

2.3.1.8 The AFCF host site will provide fire protection and emergency medical response, electrical power, raw water and sanitation.

2.3.1.9 All of the AFCF structures and functions will be located or performed on a single contiguous site.

2.3.1.10 Transport of nuclear materials and waste to and from the AFCF will be in approved containers via public roads or rail and conducted per DOT regulations.

2.3.1.11 The AFCF will provide the capability to support research, development, and demonstration (for separations and fuel fabrication) for the following fuel types or target types at both bench and engineering scales:

A. Mixed uranium and transuranic (TRU) ceramic fuel

B. Mixed uranium and TRU metal alloy fuel

C. Particle fuel, including the capability of coating and/or dispersing them in an inert matrix

D. Sphere-pac or vibropack fuels or targets

E. Fast Reactor lead test assemblies in various configurations including those designed for irradiation in various test reactors, and prototype Advanced Burner Reactor (ABR) based on requirements to be provided.

F. LWR commercial fuel (to demonstrate reprocessing capability but not the fabrication of LWR fuel).

Basis: These are the fuel types (A-E) currently being studied or developed for various advanced reactor designs. Capability with these is expected to provide resources for dealing with future fuels.

2.3.1.12 The AFCF will provide the capability to test and demonstrate gaseous emissions monitoring and control for both chemical and radiochemical species beyond current facility permit requirements (to facilitate commercial process scale-up and licensing).

2.3.1.13 The AFCF will be designed to withstand the impacts postulated by the Design Basis Threat (DBT), Design Basis Accident (DBA), and site-specific natural phenomena.

2.3.1.14 The AFCF will use, process, and store Category I quantities of SNM.

2.3.2 Functional area assumptions

2.3.2.1 Transportation packages and casks for spent fuel and materials received at AFCF are the responsibility of the sender until received at the AFCF.

2.3.2.2 Casks and materials will be inspected to assure they are received without damage. The AFCF will provide the capability to temporarily store and return off-specification or damaged material to the sender in a safe and secure manner. Receipt of welded canisters will not be permitted.

2.3.2.3 The spent nuclear fuel (SNF) sent to the AFCF is assumed to be commercial fuel assemblies (existing and future Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR)) and future ABR spent fuel. The assumed enveloping characteristics for these candidate fuels are shown in Table 2-1. These parameters will be used to: (1)

bound operating conditions for sensitivity studies that consider cost/risk trade off issues and (2) select reasonable operating conditions for the initial facility design efforts.

Table 2-1 Candidate Fuel Characteristics

Fuel Type	**Estimated BOL Enrichment Ranges**	**Fuel Assembly Mass (Approximate)**	**Estimated Possible Burnup Range**	**Estimated SNF Cooling Time Range**
Existing Commercial LWR	3% to 5% ^{235}U	1,000 kg	0 to 60 GWd/ MTIHM	5* Years to 50 Years
Future LWR	7% to 12% ^{235}U	1,000 kg	0 to 100 GWd/ MTIHM	5* Years to 20 Years
Future ABR	25% to 75% TRU	100 kg	0 to 250 GWd/ MTIHM	1 Year to 20 Years

* A one-year LWR cooling time is also to be considered for sensitivity evaluations

Basis: Best engineering judgment of range of possible burn-up scenarios and cooling times for all candidate fuels. These bounding conditions are necessary to help determine source terms for design issues related to SNF handling, radiation shielding, effluent releases, criticality safety, and confinement barriers for normal and abnormal AFCF operating conditions.

2.3.2.4 The UREX+1a process is used as the basis for the first phase of aqueous separations R&D and the basis for process equipment design. The UREX+4a process will be used to provide the basis for space layout of the aqueous process areas, and to bound the process for NEPA purposes.

2.3.2.5 Fast Reactor (FR) spent fuel received by AFCF is assumed to be free of external sodium contamination.

2.3.2.6 The AFCF will be designed to conduct engineering-scale testing for only one aqueous flow sheet at a time. A number of aqueous flow sheets may be under simultaneous investigation using various bench-scale tests.

2.3.2.7 Separations processes will provide sufficient materials for fuel fabrication and other technology demonstration needs.

2.3.2.8 The AFCF will be designed to conduct engineering-scale testing for only one pyrochemical flow sheet at a time. A number of pyrochemical flow sheets may be under investigation, in which case smaller bench-scale work may test more than one flow sheet in parallel operations.

2.3.2.9 Fuel fabrication will be capable of producing up to 10 ABR LTAs per year, which is approximately 1 MTIHM/yr.

Basis: Ten LTAs may be required to demonstrate fuel performance over the range of operating conditions and potential zone-related composition variations. In addition, the equivalent fuel mass for ten LTAs provides a good fabrication throughput demonstration.

2.3.2.10 The organizations receiving fabricated fuel and targets are responsible for their respective transportation packaging and casks.

2.3.2.11 Waste storage durations are based on assumed availability of disposal options for different waste types as follows:

A. Hazardous waste storage for up to 6 months.

Basis: Hazardous waste will be treated within AFCF or will be shipped from AFCF for treatment and/or disposal in compliance with the Resource Conservation and Recovery Act (RCRA) and other applicable regulations.

B. Low-Level Waste (LLW)/Mixed LLW (MLLW) Class A/B/C storage for up to 1 year.

Basis: Class A waste can now be disposed of. Class B/C waste will require permit modifications. This allows 8 years after initial approval of AFCF facility in June, 2008, until 2016 (the current AFCF completion date) to perform necessary permit modifications to enable disposal of this waste, and then 1 year storage beyond 2016 for storage of LLW/MLLW as it is generated.

C. High-level waste (HLW) storage for up to 10 years (including such waste forms for the La/FP, Tc, Iodine, ^{14}C, Pyro-ceramic, and Pyro-metal waste).

Basis: The current AFCF completion date is 2016, one year sooner than the current planned opening date of 2017 for the Yucca Mountain

Geologic Repository. This allows 10 years after the AFCF completion date to complete waste form characterization, schedule waste shipments, build up enough HLW to fill shipments, and send shipments.

D. Greater than Class C (GTCC) (but <100nCi/g TRU) waste storage for up to 10 years.

Basis: This waste is primarily activated metals for which a disposal precedent has been set for similar waste at Hanford. This allows 18 years after the 2008 AFCF approval date to build on the current precedent and evaluate alternatives, develop disposal pathways, schedule waste shipments, build up enough GTCC waste to fill shipments, and perform shipments.

E. GTCC (but >100nCi/g TRU, or commercial TRU) waste storage for up to 25 years.

Basis: This allows substantial time (33 years after the 2008 AFCF approval date) to either expand the Waste isolation Pilot Plant (WIPP) permit for commercial TRU waste, or develop an alternative disposal pathway for this waste.

F. Cs/Sr waste storage for up to 25 years.

Basis: There is no precedent for decay storage of this type of waste, other than the Waste Encapsulation Storage Facility (WESF) at Hanford. There is no regulatory basis for this type of decay storage facility. Substantial time is allowed to develop and implement a disposal pathway that includes decay storage for this waste.

2.3.2.12 The AFCF will be permitted as necessary under RCRA or other applicable regulations to treat hazardous, radioactive, and mixed waste produced within its processes.

Basis: Trade studies and regulatory analysis will be conducted to evaluate the extent and need for permitting by the Environmental Protection Agency (EPA).

2.3.2.13 The AFCF will be responsible for all transportation packages and casks for waste shipments from the facility (normally via lease or purchase).

3. FUNCTIONAL AND OPERATIONAL REQUIREMENTS

The primary facility functions of the AFCF are illustrated in Figure 2-1. The functional and operational requirements of each block are described in the following sections.

3.1 General Requirements

3.1.1 The AFCF shall provide the capability to support future demonstration programs for aqueous, pyroprocess, separations, remote fabrication of fast reactor fuels or transmutation targets, advanced safeguards, and advanced waste form fabrication and development. Consideration shall be given to capability to undertake potential future programs using internationally developed and/or innovative methods.

3.1.2 AFCF operations shall contribute to a fully integrated and controlled fuel cycle by separating TRU elements from spent LWR fuel and incorporating these into fuel and targets for the ABR. It shall also demonstrate recycle of TRU elements from spent Gen IV demonstration reactors, and/or fast reactor recycle fuels and targets back to fresh ABR fuel.

3.1.3 The AFCF shall support advances in developing new proliferation resistance and physical protection (PR&PP) technologies.

3.1.4 The AFCF shall house a suite of hot cell and glovebox configurations that support the transition of a proposed process or fabrication operation from individual unit bench-scale test to a fully integrated systems test operating at an engineering scale.

3.1.5 Integrated engineering-scale separations shall be conducted at a throughput rate that demonstrates: effective scale-up from bench-scale equipment, control of process variables, resolution of equipment reliability issues, potential for scale-up to commercial throughputs and integration of support systems (e.g., security, sampling, MC&A, remote decontamination and maintenance).

3.1.6 Small-scale development testing of key separations, fabrication operations, and safeguards instrumentation shall be carried out in a manner that uses facility resources that are commensurate with the associated risk, (e.g., in small hot cells, glove boxes, remote mock-up areas and fume hoods).

3.1.7 The AFCF operations shall ensure criticality safety in accordance with the latest ANSI/ANS 8.1, and ANSI/ANS-8.10 as applicable.

3.1.8 The AFCF shall provide process fluid dump tanks, critically-safe interim storage tanks, and other provisions for emptying and cleaning process vessels and piping to recover from operation upsets or equipment failure and to create flexibility to increase demonstration capabilities.

3.2 Materials Receipt and Storage Requirements

The AFCF shall be designed to address fuel cycle development issues (on a demonstration basis) that can be forecasted for the next 50 years. This includes being able to address the current inventories of SNF and their related management issues as well as those fuels that may be developed and fabricated in the future. This very broad fuel fabrication and processing requirement mandates a high degree of flexibility in multiple areas (e.g., remotely modifying and/or replacing equipment configurations in hot cells, providing timely analytical support, adjusting to the safety, safeguards and security issues that evolve with each testing program, keeping the command and control center configured to address each programmatic change).

Basis: Fifty years covers technology development and follow-on trouble shooting support for demonstration-scale fuel cycle operations that begin in the 2020s and extend for decades.

3.2.1 The AFCF shall receive intact commercial fuel assemblies (existing and future PWR and BWR) and future ABR spent fuel as described in assumption 2.3.2.3. Sensitivity studies will be conducted to help evaluate cost/risk tradeoff issues that will aid in the selection of reasonable operating conditions for the initial facility design and its related safety analysis report (SAR) and NEPA documentation.

3.2.2 The AFCF shall provide the capability to receive spent fuel and target material, including recycle transmutation fuel and shipments from test reactors, commercial reactors, Gen IV demonstration reactors, and/or fast reactors. Incoming material is expected to have been cleaned to remove surface contamination and foreign materials, such as external sodium prior to shipment to the AFCF. Provisions for receiving, inspecting, temporarily storing, conditioning and transferring SNF with high-radiation fields and high decay heat shall be provided. The facility shall provide an effective and efficient remote transfer system between the interim storage areas (both wet and dry) and the fuel preparation/dissolution cell. Wet and dry storage options must also consider leak detection, treatment options for removing contamination, isolation of fuel, fuel cutting/preparation capabilities, MC&A, security, etc.

Basis: Storage functions are required for SNF and target material to develop the AFCF technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects.

3.2.3 The AFCF shall provide the capability to receive and offload incoming materials from a truck or rail car.

Basis: Basic AFCF function required to develop the AFCF technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects.

3.2.4 The AFCF shall receive, inspect, and accept incoming materials per applicable regulatory requirements.

3.2.5 The AFCF shall provide the capability to receive and store process materials including SNM from other sites.

Basis: Basic AFCF function required to develop the AFCF technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects.

3.2.6 The AFCF shall provide the capability to safely receive, handle, and temporarily store SNM in a secure vault area and transfer quantities to other AFCF process areas.

Basis: Basic AFCF function required to develop the AFCF technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects.

3.2.7 The AFCF shall provide the capacity to store (on an interim basis) up to 40 MTIHM of LWR spent fuel and at least one MTIHM of fast reactor spent fuel, and shall allow for the batching of fuel to adjust feed stock for the head-end treatment process.

Basis: To provide one year of SNF receipts with margin to avoid any programmatic delays due to issues related to transportation.

3.2.8 The AFCF shall provide the capability to store (on an interim basis) and transport fuel to manage the flow of materials into each separations head-end preparation process.

Basis: Basic AFCF function required to maintain smooth integrated operations and timely development of AFCF technologies.

3.2.9 The AFCF shall provide equipment to remotely handle and temporarily store materials in a suitable environment that precludes loss of confinement and provides safeguards and security commensurate with the attractiveness level.

Basis: Basic AFCF function required to minimize personnel radiation exposure via as low as reasonably achievable (ALARA) guidelines and maintain safe and secure SNM storage.

3.2.10 The AFCF shall provide wet and dry spent fuels storage capability.

Basis: Basic AFCF function required to be able to store the wide variety of nuclear materials that are required for developing technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects.

3.2.11 The AFCF shall provide cask inspection, remote decontamination, spent fuel repackaging and limited repair capabilities.

Basis: Basic AFCF function required to be able to: (a) receive the wide variety of nuclear materials that are required for developing technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects and (b) develop and demonstrate improved methodologies and equipment.

3.2.12 The AFCF shall provide for safe, secure transport (SST) of SNM.

3.2.13 The AFCF shall provide the capability to provide inert cover gases where needed to help assure product purity and package integrity.

3.3 Head-End Processing

The following paragraphs describe the high-level functions related to conditioning the spent fuel into a feed stream that is chemically and physically amenable to the separations equipment and process flow sheet chemistry.

Basis: This function is required to prepare the wide variety of nuclear materials that are required for developing the separation and off-gas treatment technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects.

3.3.1 Disassembly and Batching

The AFCF shall provide the capability to receive a variety of SNF and select SNM, and to remotely inspect, disassemble, package, interrogate, and remove unwanted components (e.g., hardware, nuclear poisons, instrumentation, contaminants) prior to transitioning to the next head-end operation. The AFCF shall also provide the capability to remotely interrogate, inspect, and identify feed materials for the purpose of assessing SNM content and for blending to achieve the desired by-product isotopic concentrations.

3.3.2 Mechanical Treatment

The AFCF shall provide the capability to remove cladding, partition, and sort SNF, SNM, and other feed materials into physical dimensions that are more suitable for follow-on thermal, chemical, and/or mechanical treatment. Provisions for contamination control of fractured fuel, related fission product material, fission product gases, and airborne solid contaminants shall be provided. Contamination control shall also be provided during the transfer of conditioned material to the next head-end treatment station.

3.3.3 Thermal Treatment

The AFCF shall provide the capability to heat, within reactive or non-reactive gas streams, the feed material to temperatures that: (a) create the desired physical form (e.g., fracture the material and increase its surface area), and (b) remove the desired fission products. The AFCF shall include provisions for trapping and packaging the volatile off-gases and air-borne contaminants and remotely transferring the conditioned product to the next head-end station.

3.3.4 Dissolution

The AFCF shall include the capability to remotely charge conditioned feed material to a dissolution system that produces an adequate supply of feed solution to the separations system in a safe, timely, and integrated manner. The choice of batch or continuous dissolvers will be examined in the light of fuel types, operating parameters, desired scale of commercial operation, etc. Features to assure controlled and efficient operating conditions shall be provided (e.g., maintain criticality safety, monitor and maintain chemistry, temperature, flow, solids removal, hull removal). The dissolver off-gas (DOG) shall be controlled at a negative pressure relative to the hot cell heating, ventilation, and air conditioning (HVAC) system and treated to avoid the unwanted release of contamination and or chemicals.

3.3.5 Product Clarification

The AFCF shall include provisions for remotely removing fine solids (e.g., insoluble fission products (IFP), fuel residues and cladding fines) from the dissolver solution prior to chemical adjustment. Provisions for remotely maintaining the solids removal system and the transfer of solids to a solids packaging, interrogation, and transfer system shall also be included. Off-gas control shall be provided via the vessel off-gas (VOG) system.

3.3.6 Product Adjustment/Blending

The AFCF shall include provisions to receive clarified dissolver product and to chemically adjust the solution to meet the process flow sheet chemistry requirements for the separations systems. Other provisions shall include blending recycled off-specification streams from the separations systems, temperature control (heating and cooling), blending dissolved SNM to adjust isotopic concentrations, conducting accountability measurements, providing adjusted feed solution to the separations systems in a timely manner, maintaining contamination control, and controlling soluble poison levels if used.

3.3.7 Waste Treatment and Handling

The AFCF shall include remote handling capabilities to treat and package waste material from all parts of the head-end operations (e.g., SNF hulls, undissolved solids, SNF hardware, waste solutions, trapped off-gas fission products). Provisions to blend waste from the separations systems shall also be included, (e.g., Tc with SNF hulls).

3.3.8 Process Off-Gas Control and Treatment

The AFCF shall include provisions to remotely treat and control chemical and radiological contamination from each of the principal head-end operations, (e.g., mechanical treatment, thermal oxidative/ reductive treatment, dissolution, hull/Tc treatment). These systems shall maintain a negative operating pressure relative to the hot cell HVAC to assure unexpected breaches or leaks in the primary barrier (e.g., off-gas piping or equipment) shall retain contamination flow towards the source.

3.4 Separations Requirements

The following paragraphs define the functional requirements for all operations related to separations. Following the general separations requirements, the aqueous process requirements are addressed first, and then pyrochemical requirements.

Basis: The following statement is the basis for all of the 3.4 Subsections unless otherwise noted: Basic AFCF function required to develop the AFCF technologies identified in the Mission Need Statement for GNEP Technology Demonstration Projects.

3.4.1 General Separations

3.4.1.1 The AFCF shall incorporate an integrated engineering-scale processing system to (a) demonstrate, trouble shoot and optimize UREX+1 processing of commercial LWR spent fuel and (b) demonstrate further processing flow sheets for future commercial fuels.

3.4.1.2 The AFCF shall use surge capacity, remote maintenance, and redundant systems to decouple processes such that the integrated system is capable of demonstrating the design throughput rate and on-line availability.

3.4.1.3 The AFCF shall provide safe storage of process chemicals.

3.4.1.4 The AFCF shall provide safe and secure interim storage of SNM.

3.4.1.5 The AFCF shall provide treatment systems for removing all radioactive gaseous and particulate species, (e.g., I, noble gases, ^{14}C, tritium, fuel fines) to acceptable levels, and for removing all chemically noxious vapors and particulates, such as NOx.

3.4.1.6 The AFCF shall provide for monitoring, sampling and testing all airborne effluent streams, (e.g., DOG, VOG and Head-End Off-Gas (HOG) and building ventilation HVAC) to comply with discharge limits and achieve discharges that are ALARA.

3.4.1.7 The AFCF shall provide the capability to reconfigure process equipment and adjust demonstration systems in a rapid and timely manner, expected to be within 6 months for a complete change of flow sheet (e.g., from UREX+1 to UREX+3) while maintaining safe operating parameters and achieving ALARA personnel radiation exposure goals.

3.4.1.8 The AFCF shall be capable of processing one MTIHM of fast reactor fuel annually, using aqueous or pyrochemical processes depending on the fuel type and process selection decisions yet to be made.

Basis: Annual processing rate should exceed the expected annual discharge rate of the 250 MWt fast reactor, expected to be approximately one MTIHM, in order to respond in a reasonable time to higher than normal inventories of feed material or higher than expected by-product demand, (e.g., minimize impacts to the GNEP/fast reactor programmatic goals).

3.4.1.9 The AFCF shall produce stabilized SNM, and shall include the necessary features for safe interim storage for 12 months. An interim storage space to accommodate up to 10 years of material accumulation shall be provided to allow integrity testing.

Basis: To provide storage for integrity-testing programs and to assure adequate surge capacity between shipper and receiver.

3.4.1.10 The AFCF shall provide the capability to recover and treat material in process.

3.4.1.11 The AFCF shall manage process integration and throughputs to meet PR&PP requirements and goals.

3.4.1.12 The AFCF shall provide the capability to transfer materials (gases, liquid and solids) in a safe, secure and timely manner within the facility to assure efficient operations.

3.4.1.13 The AFCF shall provide the capability to recycle and treat and/or use off-specification material.

3.4.1.14 The AFCF shall provide the capability to re-work and treat expected off-specification waste.

3.4.1.15 The separations process areas shall be used to develop, demonstrate, and validate methods to remove constituents and specific actinide elements and fission products (or groups of such elements or fission products) from spent fuels to allow recycle of the materials to reactors or treatment, packaging, and shipment of the materials to packaging and decay storage or final disposal facilities.

3.4.1.16 The AFCF shall provide the capability to allow all separations, fuel fabrication and waste treatment processes to run independently.

3.4.1.17 The AFCF shall provide the capability to remotely sample the process streams at several locations, obtain a representative sample, and deliver the process samples to the analytical hot cells in a timely manner.

3.4.1.18 The AFCF shall provide the capability to provide timely analytical results to maintain safety, security, and targeted processing rates.

3.4.1.19 The AFCF shall provide the capability to consolidate or concentrate waste and to solidify material and waste streams.

3.4.1.20 The AFCF shall provide laboratory-scale R&D capability for improving elements of aqueous and pyrochemical processes, using hot cells, gloveboxes, or fume hoods.

3.4.2 Aqueous Separations

3.4.2.1 Separations options shall initially utilize some form of the UREX+ suite of aqueous processes for existing inventories of commercial LWR spent fuel. Modifications to this flow sheet chemistry and head-end treatment systems are expected in the course of technology development and demonstration for possible ABR fuel types.

3.4.2.2 The AFCF shall provide the functional flexibility to accommodate evaluations of a variety of flow sheets and applications that include but are not limited to those initial concepts shown in Table 3-2.

Basis: To assure adequate facility space for testing all aqueous process flow sheet options, different separations equipment (e.g., centrifugal contactors, pulsed columns, mixer settlers and batch and continuous dissolvers) and equipment configurations.

Table 3-1 Suite of UREX+ processes.

Process	Prod #1	Prod #2	Prod #3	Prod #4	Prod #5	Prod #6	Prod #7
UREX+1	U	Tc	Cs/Sr	TRU+Ln	Other FP		
UREX+1a	U	Tc	Cs/Sr	TRU	Other FP		
UREX+2	U	Tc	Cs/Sr	Pu+Np	Am+Cm+Ln	Other FP	
UREX+3	U	Tc	Cs/Sr	Pu+Np	Am+Cm	Other FP	
UREX+4	U	Tc	Cs/Sr	Pu+Np	Am	Cm	Other FP

Notes: (1) In all cases, iodine is removed as an off-gas from the dissolution process.
(2) Processes are designed for generating no liquid high-level waste.

U: uranium (removed to reduce the mass and volume of other streams)
Tc: technetium (long-lived fission product, prime contributor to long-term dose at Yucca Mountain geologic repository)
Cs/Sr: cesium and strontium (primary short-term heat generators; repository impact)
TRU: transuranic elements (Pu: plutonium, Np: neptunium, Am: americium, Cm: curium)
Ln: lanthanide (rare earth fission products)

FP: fission products other than cesium, strontium, technetium, iodine, and the lanthanides

3.4.2.3 The AFCF shall provide the capability to demonstrate all the steps in processing expected future second-generation LWR commercial fuels, including fabricating and testing the various waste forms suited to the particular UREX+ flow sheet.

3.4.2.4 The AFCF shall be capable of processing LWR spent fuel at a rate of 25 MTIHM/yr.

Basis: This processing rate was selected as representative of engineering-scale operations. Operations at this scale are necessary to resolve design issues related to process control, control systems integration, process chemistry and hydraulics, reliability and equipment scale-up. Typical testing programs start at bench scale, and then advance to engineering scale.

3.4.2.5 The AFCF shall be sized to house and operate the aqueous separations process equipment necessary for the UREX processes (see Table 3-1).

3.4.2.6 Trade studies shall be performed to examine optimal hot cell configuration size(s), layout of plant stages, availability, and flexibility in operation, plant removal and re-installation, (e.g., use of a large single cell with modular equipment on interlocking framework versus suite of cells dedicated to different stages, using floor mounted units).

3.4.2.7 If aqueous (e.g., solvent extraction technology) is selected for the processing of FAST REACTORfuels and/or targets, then the AFCF shall be capable of processing such items at a rate of 1 MTIHM/yr.

3.4.2.8 The AFCF shall provide solvent cleanup, recovery and disposition capabilities, including solvent destruction for a variety of solvent extraction and liquid ion exchange materials.

3.4.2.9 The AFCF shall provide acid recovery and re-use, and water recycle capabilities.

3.4.2.10 The AFCF shall have no high-level liquid waste discharge. Other occasional, small-quantity effluents may be sent to external facilities for treatment.

3.4.3 Pyrochemical Separations

The AFCF shall include a capability for separating fast reactor (metallic or oxide) spent fuel constituents via pyrochemical techniques.

3.4.3.1 The AFCF shall be sized to house pyroprocessing equipment operated in a remotely maintained hot cell with an inert atmosphere.

3.4.3.2 If pyrochemical is selected as the reference technology for processing fast reactor fuels and targets (see section 3.4.1.8), then the AFCF shall be designed to be capable of processing these items at a rate of 1 MTIHM/yr. If not, the design basis is likely to be changed.

3.4.3.3 The AFCF shall provide an engineering-scale pyrochemical system for converting oxide feed material to metal.

3.4.3.4 The AFCF shall include provisions to ensure the hot cell high-temperature processes provide adequate HVAC features to maintain desired cell temperatures and inert gas purity, (e.g., maintain desired operating temperatures for the equipment, thereby precluding damage to temperature-sensitive items and maintaining oxygen and water vapor levels in inert gas of up to several vppm). Inert gas shall be recycled to the degree practicable.

3.4.3.5 The pyroprocessing section of the AFCF shall include features that assure the timely availability of the remote equipment required for operations and maintenance.

3.4.3.6 The AFCF shall provide electrochemical and other pyrochemical actinide-group equipment to support recovery of U-Pu-minor actinide metal stream, which can be used for remote fabrication of recycled fast reactor fuel.

3.4.3.7 The AFCF shall provide pyrochemical sampling equipment that is remotely maintained and designed to sample the various pyrochemical by-product and waste streams, and operate dependably in high temperature and high radiation fields.

3.4.3.8 The pyrochemical separation process shall receive feed material that has been properly conditioned by a pyrochemical head-end system.

3.5 Separations Material Handling and Storage Requirements

3.5.1 The AFCF shall provide the capability to sample, interrogate and/or package blended separations and fuel feed materials.

3.5.2 The AFCF shall provide the capability to safely and securely store packaged fuel fabrication feed materials for up to one year.

3.5.3 The AFCF shall provide for material monitoring, security, radiation shielding and confinement, remote operations, and maintenance support, as needed.

3.5.4 The AFCF shall provide the capabilities and equipment to concentrate, solidify, or otherwise immobilize product, as needed.

3.5.5 The AFCF shall provide the capabilities to monitor and transfer various amounts and kinds of nuclear material within the facility in a safe and timely manner.

3.5.6 The AFCF shall provide the capability to safely and securely package nuclear materials for off-site shipment.

3.6 Fuel Feed Material and Scrap Conditioning Requirements

3.6.1 The AFCF shall provide the capability to blend combinations of in-process and external source materials such as wet chemical solutions, molten metals, or dry powders to achieve the required elemental and isotopic compositions required for fuel fabrication.

3.6.2 The AFCF shall provide the capability to chemically adjust blended feed materials to achieve the needed stoichiometry or to meet specifications for chemical purity.

3.6.3 The AFCF shall provide the capability to handle metallic feed for metal fuel fabrication.

3.6.4 The AFCF shall provide the capability to convert pyrochemical metallic fuel products to oxides prior to feeding into the ceramic fuel fabrication process.

3.6.5 The AFCF shall provide the capability to physically sort and adjust blended feed material particle size and morphology as required for fuel fabrication.

3.6.6 The AFCF shall provide the capability to recover fuel materials and re-blend for reuse in fuel fabrication.

3.6.7 The AFCF shall provide the capability to transfer unblendable fuel scrap back to separations for actinide element recovery.

3.6.8 The AFCF shall provide the capability to recover transuranics from scrap, fuel fabrication off-specification material, and clean-up residues.

Basis: The above requirements address the expected needs for fabricated fuel quality (3.6.1 ,2, and 6), address the needs for processing and fabrication of the range of fuel types being developed for various advanced reactor designs (3.6.3 & 4), and provide for waste minimization (3.6.5, 7 & 8).

3.7 Fuel Fabrication Requirements

3.7.1 The AFCF shall provide the capability of developing a variety of advanced fuel types and transmutation targets in varying elemental blends and configurations (see Section 2.3.1.12).

3.7.2 The initial primary fuels to be demonstrated in AFCF shall be mixed oxide or metal alloy fuels.

Basis: Of all fuel types suggested for fast reactor use, oxide and metal fuels have been developed and tested to the greatest extent. It is likely that one of these fuel types will be used for the ABR. The UREX+1 reference flow sheet separates TRU as a group, so all actinides must be incorporated into transmutation fuels.

3.7.3 The AFCF shall support hot development work as well as produce bench-scale quantities of many different fuel types for examination of their physical and thermal properties before and after irradiation.

3.7.4 The AFCF shall perform engineering-scale fuel fabrication operations. The capability to efficiently modify, remove, and reinstall equipment shall be provided to support development, testing, and evolution of prototypic fuel fabrication methods.

3.7.5 The AFCF fuel fabrication line shall be designed to minimize the amount of waste generated.

3.7.6 The AFCF shall manufacture, test, and ship fuels ranging from test pins for irradiation in small research and test reactors up to full size LTAs to support prototypic scale operations for different fuel types.

3.7.7 The AFCF shall handle a variety of fuel blends from conventional uranium fuels to plutonium-bearing fuels to fuels containing substantial quantities of minor actinides (Np, Am, Cm).

3.7.8 The AFCF shall provide the capability to convert an aqueous process transuranic product into a homogeneous metal or ceramic fuel material.

3.7.9 The AFCF fuel fabrication function shall provide efficient access to a radiochemistry and fuel characterization laboratory to provide rapid turnaround on chemical analysis, isotopic analysis, and fuel physical and thermal properties. The use of on-line real time monitors (e.g., spectroscopic and electrochemical meters) is favored wherever practicable.

Basis: Minimization of waste and process efficiency demand that time delays at hold points requiring chemistry verification of product quality be minimized. Minimizing the time required for *verification of chemical composition acceptability is essential for maintaining efficient operations.*

3.7.10 The AFCF shall provide capability to conduct all necessary quality control (QC) inspections and prepare quality assurance (QA) documentation in accordance with appropriate DOE, NRC, and customer requirements.

3.7.11 The AFCF shall provide the capability to sample fuel products and materials and conduct necessary QC inspections to meet all applicable requirements.

3.7.12 The fuel fabrication function shall be capable of receiving feed materials directly from other areas of the AFCF.

3.7.13 The AFCF shall provide the capability to handle pyrophoric or chemically reactive material in an inert atmosphere.

Basis: Metal and nitride fuel alloys, sodium, and other materials associated with fuel processing and fabrication can be highly reactive and require an inert atmosphere.

3.7.14 The AFCF shall provide the capability to fabricate TRU-bearing ceramic recycle fuel or metallic fast reactor fuel pins for a test fast reactor and LTAs for an ABR.

3.7.14.1 The AFCF shall be capable of processing one metric ton of uranium (U) and TRU plutonium (Pu), americium (Am), neptunium (Np) and curium (Cm) heavy metal annually into fuel.

3.7.14.2 The AFCF shall provide the fuel fabrication throughput to produce 10 ABR LTAs annually.

Basis: One MTIHM/yr fuel fabrication throughput is sufficient to provide 10 ABR LTAs relevant to typical reactor designs being considered, as well as being sufficient to provide driver fuel feed for a typical fast test reactor.

3.7.15 The AFCF shall provide the capability to manufacture fast reactor lead test assemblies.

3.7.15.1 The AFCF shall provide the capability to fabricate FAST REACTORlead test assemblies in various configurations, including those designed for irradiation in fast test reactors, and prototype ABR, based on requirements to be provided.

The fuel pin and bundle design basis for conceptual design shall be the Fast Flux Test Facility fuel.

Basis: Mission Need Document - To help establish the US as an international leader in advancing the use of nuclear power. Fast reactors currently in an operational state may be used to test fuel design for the ABR.

3.7.15.2 Concurrent fabrication of metal and ceramic fuel is not required. Process equipment shall be designed to change out as necessary to fabricate ceramic or metal fuel.

3.7.16 The AFCF shall provide the capability to perform metallurgical bonding of metallic fuel pins to their cladding using sodium metal.

3.7.17 The AFCF shall provide fuel assembly storage to provide space and controls for staging of fuels in preparation for shipment.

3.7.18 The AFCF shall provide the capability to recycle fuel material scrap for incorporation back into the fuel-fabrication process.

3.7.19 The AFCF shall provide laboratory-scale R&D capability for improving elements of fuel fabrication processes, using hot cells, gloveboxes, or fume hoods.

3.8 Waste Treatment, Handling and Storage Requirements

3.8.1 All generated effluent, waste, and products shall be treated as required for disposition or release in an environmentally sound, safe form that meets all applicable waste treatment and emission regulations and complies with the WAC for applicable licensed disposal facilities.

3.8.2 All waste that requires temporary storage pending disposal pathway development shall be stabilized in the expected final waste form, and shall not be stored as a liquid in long-term storage.

3.8.3 The AFCF shall provide for final waste form disposition, by either treating the waste or arranging for approved waste treatment by others.

3.8.4 Temporary waste storage shall be provided to decouple waste generation from treatment, shipping, and disposal. Storage shall be interim and compliant with material-specific requirements.

3.8.5 The AFCF shall provide the capability to demonstrate advanced waste treatment technologies, including utilities, space, instrumentation, analysis, and storage.

3.8.6 Waste treatment technology development shall include facility support for metering liquid, solid, slurry feed, and support for chemical mixing and storage.

3.8.7 Waste treatment technology development shall include facility support for melting and/or sintering at temperatures of up to 1800°C.

Basis: 1,800°C is representative upper limit for waste treatment systems.

3.8.8 Waste treatment technology development shall include facility support for blending and encapsulating in media.

3.8.9 Waste treatment technology development shall include facility support for gas heating, cooling, wet scrubbing, and dedicated connections to facility non-radioactive and radioactive off-gas vents.

3.8.10 The AFCF shall treat, monitor, and meet regulatory requirements for all of its effluent streams.

3.8.11 In addition to providing facility support for nominal off-gas treatment to meet expected baseline R&D facility emission requirements, the facility shall provide support and space for developing and testing potential future off-gas treatment technologies for commercial operations such as cryogenic capture of noble gases, condensation of tritiated water vapor, and sorption of iodine and carbon (as CO_2).

3.9 Shipping Requirements

3.9.1 The AFCF shall provide packaging capability.

3.9.2 The AFCF shall provide temporary storage capacity.

3.9.3 The AFCF shall provide the capability to ship LTAs.

3.9.4 The AFCF shall provide the capability to ship new waste forms.

3.9.5 The AFCF shall provide the capability to ship laboratory and secondary waste (TRU, LLW, hazardous, industrial, etc.).

3.9.6 The AFCF shall provide the capability to ship HLW in accordance with DOE requirements.

3.9.7 The AFCF shall provide the capability to prepare packages for shipping (decontamination, characterization, waste certification, etc.).

3.9.8 The AFCF shall provide the capability to ship SNM and provide safe haven areas for SST vehicles.

3.9.9 The AFCF shall provide the capability to maintain and repair shipping and packaging containers.

Basis: This includes waste packages that are the responsibility of AFCF and also minor repair to containers received by AFCF. Damaged containers received at AFCF may need some repair before being returned to the sender (or container owner).

3.9.10 The AFCF shall provide qualified shipping and packaging containers.

3.10 Facility Support Requirements

The facility support functions of the AFCF include the following:

- Bench-scale testing
- Cold remote mock-up capability
- Analytical services
- Effluent management
- Cold chemical makeup
- Instrumentation and control
- Infrastructure
- Remote handling
- Atmospheric and radiological confinement control.

The requirements for each support function are provided in the sections below.

3.10.1 Bench-Scale Testing Requirements

3.10.1.1 The AFCF shall provide the capability to perform laboratory and bench-scale testing to support engineering-scale work.

3.10.1.2 The AFCF shall provide the capability to perform process research, development, and testing in inert atmosphere hot cells, glove boxes, and fume hoods.

3.10.1.3 The AFCF shall provide the capability to remove equipment components from engineering and bench-scale process lines and decontaminate them sufficiently for either appropriate maintenance or disposal.

3.10.2 Cold Remote Mock-Up Capability

3.10.2.1 The AFCF shall provide a cold mock-up and equipment development area to support the assembly, fit-up, and functional testing of equipment, and training prior to introduction to radiological areas.

3.10.2.2 The AFCF shall provide high-bay capability sized for the largest piece of process equipment.

3.10.3 Analytical Services Requirements

3.10.3.1 The AFCF shall provide analytical capability that remotely receives samples from throughout the AFCF.

Basis: A list of potential analytical services equipment and capabilities required to support the AFCF will be provided in the Conceptual Design Criteria Document.

3.10.3.2 Provisions for archiving analytical samples shall be provided. Analytical samples, residues and discarded archive samples shall be returned to the processes for recovery wherever practical.

3.10.3.3 The analytical services area shall provide the shielding, contamination control, safeguards and security, hazardous material control and remote capabilities necessary to safely perform all analytical measurements, (e.g., hot cells, glove boxes and vented hoods).

3.10.3.4 The AFCF shall include offices, change rooms, meeting rooms, central control office, storage areas (for chemicals, beakers, sample bottles, etc.), and typical analytical support features for maintaining equipment, and storing contaminated spare items.

3.10.3.5 The AFCF shall provide an analytical waste treatment and packaging system and provide features for safely transferring material in and out of contamination control areas.

3.10.3.6 The analytical area shall include security features that are implemented on a graded approach, based on all applicable requirements.

3.10.3.7 The AFCF shall provide the capability to conduct nondestructive inspections and material analysis.

3.10.4 Cold Chemical Makeup requirement

3.10.4.1 The AFCF shall provide the capability to store, prepare and deliver reagents and process gases as needed to support processes.

3.10.5 Infrastructure Requirements

3.10.5.1 The AFCF shall provide warehouse space for receipt and storage of supplies, materials, spare equipment, etc.

3.10.5.2 The AFCF shall provide facility features and remote capabilities to support maintenance and testing of contaminated equipment (maintenance of remote-handling systems and process equipment repair).

3.10.5.3 The AFCF shall provide maintenance areas for nonradioactive equipment.

3.10.5.4 The AFCF shall provide personnel decontamination facilities. Change rooms shall be strategically located for workers to minimize contamination control issues.

3.10.5.5 The AFCF shall provide secure storage, including interim storage, for the facility by-products and feed stocks as required.

3.10.5.6 The AFCF shall provide non-secure storage for the facility by-products and feed stocks as required.

3.10.5.7 The AFCF shall provide decontamination and packaging areas for repairing or dispositioning failed process equipment, for packaging contaminated items for disposition (e.g., contaminated HEPA filters) and for cleaning contaminated items for return to service (e.g., SNF shipping cask or SNM shipping container).

3.10.5.8 The AFCF shall provide facilities for instrument calibration of monitoring and testing equipment (M&TE).

3.10.5.9 Critical power supply and HVAC systems for the command and control center shall be able to operate independently of the AFCF and its operational status.

3.10.5.10 The AFCF shall provide necessary back-up power for critical systems, including process control, MC&A, security, lighting, and other identified systems to provide continuous operation if primary power is lost.

3.10.5.11 The AFCF shall provide "clean" (high quality) electrical power for I&C, analytical laboratories, and MC&A.

3.10.5.12 The AFCF shall provide an integrated office space complex, with conference rooms and support areas.

3.10.5.13 The AFCF shall provide or incorporate into an existing capability a sewage treatment and disposal system.

3.10.5.14 The AFCF shall provide sufficient electrical power from off-site sources for all facility processes.

3.10.5.15 The AFCF shall provide for communications between persons, facilities and operations.

3.10.6 Remote Handling Requirement

3.10.6.1 The AFCF shall meet/maintain ALARA levels using remote operation and maintenance methods as required.

3.10.6.2 Remote handling shall be supported by viewing systems that optimize the desired remote capability and retain high reliability.

3.10.6.3 A testing station shall be provided for new and repaired remote handling equipment to help detect problems prior to installation.

3.10.7 Atmospheric and Radiological Confinement Control Requirements

3.10.7.1 The AFCF ventilation system shall assure airflows from areas of less radiological contamination potential to areas of more contamination potential for normal and abnormal operating conditions.

3.10.7.2 The pressure differentials within the AFCF shall be maintained between confinement zones to assure proper airflow direction.

3.10.7.3 Filtration shall be used to maintain contamination control as close as possible to the point of release.

3.10.7.4 Air flow within AFCF shall be divided into zones and monitored to identify the source of any abnormal radiological releases.

3.10.7.5 Backup protective features (e.g., HEPA filtration, blowers, and power supply) shall be provided as required.

3.10.7.6 The AFCF shall provide continuous radioactive emission monitoring to meet 40CFR61 for a Class 1 facility.

3.10.7.7 Isokinetic sampling for process off-gas and HVAC exhaust air shall be provided to assure representative samples are collected.

3.10.7.8 The AFCF shall demonstrate, at an engineering scale, all of the atmospheric treatment systems that may be necessary to operate a commercial reprocessing facility, (e.g., removal of ^{85}Kr, tritium, and ^{14}C).

3.10.7.9 The AFCF HVAC system shall be designed in zones to provide independent availability of key processes, i.e., allow separations area to operate independently of upset conditions in the fuel fabrication area or SNF storage areas.

3.11 Safeguards and Security

3.11.1 The AFCF shall provide a system for addressing requirements for licensing AFCF using current technologies to the greatest extent possible.

3.11.2 The AFCF shall provide bench-scale and engineering-scale areas to demonstrate advanced safeguards monitoring, sampling, and analytical systems. These systems shall be capable of interfacing with multiple points in the process, interfacing with multiple physical states (i.e., liquid, solid, gaseous), and providing representative process information.

3.11.3 The AFCF shall provide a dedicated IAEA Inspector room with work space and data retrieval capabilities. The AFCF shall also include dedicated IAEA analytical chemistry laboratory space with in-process SNM measurement equipment and data transmission capabilities on a selected basis.

3.11.4 The AFCF shall apply state-of-the-art physical safeguards and physical protection systems, as required, to the facility, its equipment, content, and nuclear materials.

3.11.5 The AFCF shall provide the capability to test and demonstrate the next generation of methodology and technology that relate to PR&PP performance.

3.11.6 The AFCF shall be encompassed by three security layers. SNM shall be located (used, processed, or stored) within the Material Access Area (MAA) inside a Protected Area (PA) with an additional security layer, an Extended Detection Area (EDA), beyond the PA layer. The SNM shall be stored in a vault of substantial construction, capable of incorporating an active denial system and adequately protected by a defense-in-depth physical barrier strategy.

3.11.7 Vehicle and personnel barriers shall be incorporated into each security layer. Barrier design shall provide sufficient delay time for the Protective Force (PF) to engage unauthorized entry and sufficient "stand-off" distance to protect the facility against the Design Basis Explosives Threat. Aircraft barriers shall be in place to deny or deter use of aircraft for adversary insertion and facility sabotage scenarios.

3.11.8 The PF shall be armed and equipped with state-of-the art weaponry, tactical equipment, vehicles, and communication systems to ensure PF survivability. The primary mission of the PF is the protection of SNM from theft, sabotage, and unauthorized control.

3.11.9 Access controls shall be in place to ensure that unescorted access to the AFCF is restricted to appropriately cleared and authorized personnel.

3.11.10 The intrusion detection systems shall communicate to and annunciate at both a Central Alarm Station (CAS) and a Secondary Alarm Station (SAS). The alarm system shall use redundant, independently routed, or separate communication paths and meet the requirements for Safeguards and Security Alarm Management and Control Systems (SAMACS). The CAS shall be built underground.

3.11.11 Except for off-site shipping, it shall not be necessary to transport SNM or high-level radioactive material outside facility buildings.

3.12 Instrumentation and Control (I&C)

The AFCF shall provide I&C infrastructure that is flexible, modular, state-of-the-art and designed for ease of maintenance.

3.12.1 Data Collection

3.12.1.1 The AFCF shall provide a data collection system with the accuracy, reliability, physical constraints, life cycle, quality, and security to support development, test, production and R&D requirements.

3.12.1.2 The AFCF shall provide process control systems to collect all the information that is required to maintain safe, secure and reliable process control, MC&A, and modeling data for all of its development programs and technology demonstrations.

3.12.1.3 The AFCF shall maintain a standards control program that meets applicable quality assurance (QA) and security requirements for the information.

3.12.1.4 The AFCF analytical area shall provide the remote capabilities necessary to safely perform all analytical measurements.

3.12.2 Data Management

3.12.2.1 The AFCF shall provide data handling capacity for distributing collected and modeled data throughout the facility.

3.12.2.2 The AFCF shall provide data distribution for secure deployment of data collection and control devices with minimal hard wiring or infrastructure modifications due to process modifications.

3.12.2.3 The AFCF shall provide for secure storage, retrieval and distribution of all data.

3.12.3 Control Action

3.12.3.1 The AFCF shall provide control systems to ensure the safe and environmentally sound regulation and interlocking of processes for all of its development programs and technology demonstrations.

3.12.3.2 The AFCF shall provide control response systems for maintaining operations, MC&A requirements, and technology demonstration goals.

3.12.3.3 The AFCF shall provide the remote capabilities necessary to safely perform control actions.

3.12.3.4 The AFCF shall provide intelligent, automated systems for operations, oversight, and science.

3.12.4 Material Accountability

3.12.4.1 The AFCF shall provide material accountability, including but not limited to, SNM, other nuclear materials, and chemicals.

3.12.4.2 The AFCF shall provide the capability to develop and demonstrate instrumentation for near real-time accountability.

3.12.4.3 The AFCF shall be equipped to provide input to a computerized system to maintain material inventory management throughout the facility.

3.12.5 Human Data Interface

3.12.5.1 The AFCF shall provide a central command and control center.

3.12.5.2 The AFCF shall provide ergonomically sound interaction of personnel with facility and analytical process systems.

3.12.5.3 The AFCF shall provide intelligent, automated interfaces for operations, oversight, and science.

3.12.6 Modeling

3.12.6.1 The AFCF shall provide for embedding of models and associated data within the data collection and controls algorithms.

3.12.6.2 The AFCF shall provide the modeling framework for scientific, material accountability, and process development applications.

3.13 Quality Assurance

3.13.1 The AFCF QA Program (QAP) shall implement the QA Criteria listed in DOE Order 414.1C, Quality Assurance, Section 4B and 10 CFR 830 Subpart A, Quality Assurance Requirements, Section 830.122 using a graded approach as defined in the Project QAP document.

3.13.2 The AFCF QAP shall use national consensus standard NQA-1-2000, Quality Assurance Requirements for Nuclear Facility Applications to develop and implement the AFCF QAP.

3.13.3 The AFCF QAP shall integrate, as defined in the Project QAP document, the quality management system requirements as defined in DOE O 414.1C, the suspect counterfeit measure process defined in DOE O 414,1C, Attachment 3, the Corrective Action Management Program as defined in DOE O 414,1C, Attachment 4, the Safety Software Quality Requirements as defined in DOE O 414,1C, Attachment 5, and other quality or management system requirements in DOE Directives and external requirements, as applicable.