Used Fuel Research and Development Test and Validation Facility Cost Study

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition
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Executive Summary

The U.S. Department of Energy Office of Nuclear Energy (DOE-NE), Used Nuclear Fuel Storage and Transportation Research, Development ,and Demonstration Plan (DOE 2012a) outlines the Department of Energy's (DOE) approach for conducting research, development, and demonstration (RD&D) to assure safe and secure storage and transportation of the nation's used nuclear fuel (UNF) until final disposition is achieved. Over the past year, the concept of implementing its recommendations at a new "greenfield" consolidated storage facility (CSF) coupled with a test and validation facility (T&VF) has expanded to a variety of alternatives including the reuse and/or modification of existing DOE facilities.

The scope of this task was to develop a rough order of magnitude (ROM) cost study for a "greenfield" T&VF co-located with a CSF in support of DOE-NE's mission to identify alternatives for managing the back end of the fuel cycle. The T&VF will benefit other DOE-NE missions by providing facilities that will have the capability to 1) inspect and examine UNF and/or High Level Waste for commercial utilities, NRC, and DOE; 2) support R&D for Small Modular Reactors and the front end of the fuel cycle; and 3) support other fuel cycle research and development activities which require radioactive materials from commercial power operations.

A team of subject matter experts used Savannah River Site models to develop costs based on the conceptual design scope described in sections 4.0 and 5.0. Application of these cost models resulted in an estimated cost of $1.2 Billion.

Other project costs (e.g., project support, design authority, start-up testing, and operations training, etc.) were not included but are expected to be ~30% of the Total Estimated Cost (TEC). Other project costs (OPC) will be dependent upon contracting strategy and costing practices associated with the facility owner and location.

Based on uncertainties associated with constructing a complex, first of a kind, hardened, high radiation facility, the team assumed a contractor's contingency range of 20% to 50% and a risk contingency range of 0% to 25%. Application of the combined contingencies (20% to 75%) resulted in a ROM TEC of between $1.5 and $2.2 Billion. Establishing a high and low range using the contingency ranges is normal practice for a ROM case study. Table S-1 summarizes the T&VF ROM TEC.

Table S-1 T&VF Total Estimated Cost

	Contingency		**Dual Process Lines and Mock-up Facility Estimated Cost ($ Millions)**	
	Low	High	Low	High
Scope Baseline	N/A	N/A	$1,232	$1,232
Contractor Contingency	20%	50%	$246	$616
Risk Contingency	0%	25%	$0	$308
Total Estimated Cost	**N/A**	**N/A**	**$1,478**	**$2,156**

Dual processing lines and a mock-up facility were included in the conceptual design to reduce the risk associated with operating a complex first of a kind facility for a minimum of 40 years which was assumed to be the life of the facility. As a sensitivity check on these major cost drivers, the team completed parametric cost analyses for the two design variations described below and summarized in Table S-2.

Design Variation A: Dual processing lines with-out a mock- up facility - The baseline TEC would decrease by ~$150 to $220 Million. The consequence of eliminating the mock-up facility would be reductions in the facility's ability to adjust to system and/or operating changes in a non -radioactive environment.

Design Variation B: Single process line with mock-up facility - The baseline TEC would decrease by ~ $530 to $780 Million. The consequence of eliminating one of the dual processing lines would be the reduction in the ability to continue to operate while major systems, structures, or components are being maintained, during facility outages, or if process upset conditions occur.

Table S-2 Facility Design Variations TEC

Facility Design Variations	**Total Estimated Cost ($ Millions)**	
	Low Cost	High Cost
Dual Process Lines and Mock-up Facility (Estimate Baseline Rounded)	$1,480	$2,160
Variation A: Dual Process Lines with-out Mock-up Facility	$1,330	$1,940
Variation B:Single Process Line with Mock-up Facility	$950	$1,380

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Acronyms

ACCM	Automated Canister Cutting Machine
ACWM	Automated Canister Welding Machine
ALARA	As Low As Reasonably Achievable
ALTC	Analytical Line Transfer Conveyor
CCR	Cranes Control Room
CCS	Central Computer System
CCTB	Cask and Canister Transfer Bay
CRB	Cask Receipt Bay
CSF	Consolidated Storage Facility
CTS	Cask Transfer Shuttle
DB	Disassembly Bay
DCR	Disassembly Control Room
DE	Destructive Examination
DOE	Department of Energy
F&Rs	Functions and Requirements
FAS	Fuel assembly Shuttle
FASC	Fuel Assembly Support Can
FEG	Field Emission Gun
FRSC	Fuel remnant Storage Can
GWd	Gigawatt-days
HEPA	High-Efficiency Particulate Air
HKED	Hybrid K Edge Densitometry
ICP-AES	Inductively Coupled Plasma-Mass Spectrometry
ICP-MS	Inductively Coupled Plasma-Atomic Emission Spectrometry
ISSCP	Instrumented SNF Storage Cask Pad
MCR	Main Control Room
MTHM	Metric Ton of Heavy Metal
MU	Mock Up
MWHB	Maintenance and Waste Handling Building
N/A	Not Applicable
NDE	Non Destructive Examination
NE	Nuclear Energy
NRC	Nuclear Regulatory Commission
NWTRB	Nuclear Waste Technical Review Board
OPC	Other Project Cost
PB	Processing Building
PCS	Process Control System
PVV	Process Vessel Ventilation
RB	Return Bay
RBCR	Returns Bay Control Room
R&D	Research and Development
RD&D	Research Development and Demonstration

ROM	Rough Order of Magnitude
SA	Sample Analysis
SEM w/EDS	Scanning Electron Microscope with Energy Dispersive Spectroscopy
SRNL	Savannah River National Laboratory
SPMT	Self-Propelled Modular Transporter
T&VF	Test and Validation Facility
TBD	To Be Determined
TBV	To Be Verified
TEC	Total Estimated Cost
UNF	Used Nuclear Fuel

TBD (To Be Determined) and **TBV** (To Be Verified) are used in this document to identify information that should be developed and/or clarified. A **TBD** indicates places where descriptive information or quantitative values are not yet available. A **TBV** is used when descriptive or quantitative information is provided but requires further development because it:

- Is preliminary and unapproved;
- Involves an uncertain design feature;
- Has insufficient technical justification;
- Needs verification; or
- Creates a discrepancy or inconsistency.

1. Mission Need

The U.S. Department of Energy Office of Nuclear Energy (DOE-NE), *Used Nuclear Fuel Storage and Transportation Research, Development ,and Demonstration Plan* (DOE 2012a) outlines the Department of Energy's (DOE) approach for conducting research, development, and demonstration (RD&D) to assure safe and secure storage and transportation of the nation's used nuclear fuel (UNF) until final disposition is achieved.

The scope and objectives described in the referenced plan may be best summarized by the R&D recommendations contained in the Nuclear Waste Technology Review Board (NWTRB) report[a] on the same topic.

"The recommended research programs investigate the following issues:

- *Understanding the ultimate mechanical cladding behavior and fuel-cladding degradation mechanisms potentially active during extended dry storage, including those that will act on the materials introduced in the last few years for fabrication of high burn-up fuels*
- *Understanding and modeling the time-dependent conditions that affect aging and degradation processes, such as temperature profiles, in situ material stresses, quantity of residual water, and quantity of helium gas*
- *Modeling of age-related degradation of metal canisters, casks, and internal components during extended dry storage*
- *Inspection and monitoring of fuel and dry-storage systems to verify the actual conditions and degradation behavior over time, including techniques for ensuring the presence of helium cover gas*
- *Verification of the predicted mechanical performance of fuel after extended dry storage during cask and container handling, normal transportation operations, fuel removal from casks and containers, off-normal occurrences, and accident events*
- *Design and demonstration of dry-transfer fuel systems for removing fuel from casks and canisters following extended dry storage."*

These recommendations apply to the storage and transportation of any type of used fuel. However, the near-term objective within the R&D scope is to address the existing used fuel discharged from existing commercial LWRs. Under this objective, there is a high priority to investigate extended storage and transportation of high burn-up fuels ($\geq$ 45 GWd/MTHM) since reactor operations are moving to higher burn-up and there is limited understanding of the impacts of higher burn-ups on long-term storage.

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[a] "Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel" NWTRB report, December 2010.

2. Document Scope

Over the past year, the concept of implementing DOE's RD&D plan recommendations at a new "greenfield" consolidated storage facility (CSF) coupled with a test and validation facility (T&VF) has expanded to a variety of alternatives including the reuse and/or modification of existing DOE facilities. However, in support of its mission to identify alternatives for managing the back end of the fuel cycle, DOE-NE requested Savannah River National Laboratory (SRNL) to develop a rough order of magnitude (ROM) cost study for a "greenfield" T&VF located with a CSF. This activity fulfills the level 3 milestone (M3FT-12SR0802073) described in Work Package Number FT-12SR080207.

This ROM represents an estimate at one end of the spectrum of alternatives for a complete new stand-alone facility. This work will be used to support cost estimates for other viable alternatives, as appropriate. Statements made in this report that refer to specific numbers of components, required capabilities of the facility, or size of the facility are based on the *Used Fuel Research and Development Tests and Validation Facility Functions and Requirements* (DOE 2012b) document that provides the basis for planning a green field stand-alone facility. However, no decisions have been made with regard to fielding such a facility.

3. Testing and Validation Overview

For the greenfield alternative, the anticipated data needed to meet the objectives of the DOE-NE RD&D Program will be obtained by:

i) **Dry storage *in-situ* inspection and monitoring**, where storage conditions and the storage system components will be inspected and monitored; and
ii) **Detailed, out-of-cask testing and validation,** where non-destructive (NDE) and destructive examination (DE) methods will be provided to collect data on fuel and storage system materials' performance.

The dry storage *in-situ* inspection and monitoring will be accomplished at a stand-alone CSF.

The detailed, out-of-cask testing and validation using non-destructive (NDE) and destructive examination (DE) methods will be accomplished at the T&VF. The T&VF will be co-located with the CSF and will be one of several interrelated modules.

4. Consolidated Storage Facility Description

Based on the functional requirements (DOE 2012b), the CSF will be a UNF dry storage area where the following components will be examined via *in-situ* inspection and monitoring:

- CSF storage pad and/or vault
- Selected dry storage casks and associated canisters
- New instrumented casks loaded with selected UNF

One UNF storage cask pad will be provided for T&VF use at the CSF with space for placement of up to three instrumented casks and up to six non-instrumented storage casks. The UNF storage cask pad will measure approximately 3 feet deep, 67 feet long, and 30 feet wide. It will be surrounded by compacted aggregate suitable for heavy carrier traffic access. Figure 4-1 provides a representative image of the instrumented UNF storage cask pad and casks.

Figure 4-1 Representative Image of T&VF Instrumented UNF Storage Cask Pad and Casks

5. Test and Validation Facility Description

Based on the functional requirements (DOE 2012b), below is a description of the T&VF. All dimensions provided with the figures in this section are not to scale and were provided as input to the facility layout. The representative facility dimensions and layout (including plan, elevation, and section views) have been provided in Appendix A.

5.1 Through-put

It is anticipated that six storage casks per year will be the typical annual throughput for the T&VF resulting in extraction, segmentation and examination of approximately six fuel rods per year from six fuel assemblies. Included in the six casks per year annual throughput will be up to three instrumented casks per year.

5.2 Physical and Operating Overview

Fuel cask receipts occur within the Cask Receipt Bay (CRB) of the facility, which is a steel framed, high bay, metal structure equipped with overhead cranes for cask loading and unloading. The adjacent T&VF Processing Building (PB) is a hardened concrete, seismically designed, four level building, equipped with two high bay shielded areas for cask and canister opening, fuel assembly extraction, disassembly, and examination.

Downstream of the disassembly high bay fuel handling area is a shielded analytical area for fuel examination. The analytical area includes multiple dedicated and instrumented test stations which are provided to allow individual UNF segments and their constituents to be examined and analyzed. The analytical area will include an automated sample conveyor system which will support two parallel and interconnected central processing lines on the 0’ Elev. processing floor.

The conveyor system is positioned behind shielded observation windows and remotely controlled. It can be programmed to transfer both sample and analytical material between designated stations along the main transfer lines or transverse work stations and/or shielded glove boxes connected to each main line.

The conveyor system can be programmed for permissive travel control based on logical position conditions along the conveyor system (e.g., interlocking air lock controls along the transfer line, criticality control proximity conditions, sample traffic or routing control etc.).

Analyzed material and waste will travel to the end of the transfer line within the T&VF PB where it will be packaged and transferred to an adjacent waste handling staging facility for transfer offsite or waste staging. Liquid waste from analytical operations will be collected and treated to produce a solidified form suitable for disposal as low level waste. The adjacent facility will also provide infrastructure for 1) electrical, mechanical and instrumentation equipment; 2) hot and cold maintenance; 3) dry and liquid cold processing chemical receipt and storage; and 4) bulk gas storage as needed for processing.

Connected to the T&VF PB is a steel framed T&VF Mock Up (MU) Facility. In order to simulate actual physical conditions which might be needed for new technology or revised operations configurations over the life of the facility, the MU Facility will also accommodate up to 10 or more of the 20 work stations positions which exist in the actual T&VF radioactive operations processing line.

5.3 Systems and Components Description

5.3.1 Cask Receipt Bay

Storage, transfer, and instrumented casks are first received in one of the two cask receipt bays (CRB) on facility or offsite carriers, where they are rotated from a horizontal position to a vertical position and readied for lifting from the carrier using one of the two 200 ton overhead bridge cranes serving the receipt bays. Carrier access to the bays is via a combined rail or truck carrier access line which is configured for pass through access so that two cask handling lines may be operated.

Two processing lines are provided for the T&VF to provide back up and supporting infrastructure for such a complex facility and to allow for concurrent receipt and release operations, as needed, considering the extent of handling operations necessary to receive and unload material and the follow-on operations needed to repackage & reseal fuel canisters, reload them into casks and release the packages for ongoing storage. Handling and processing sequences in the following sections will be discussed in terms of processes occurring in one line, realizing that the parallel processing line performs similar steps.

Upon receipt in the CRB, the cask is lifted from the carrier and placed vertically on a cask transfer shuttle (CTS) located adjacent to the carrier line and outside of the cask and canister transfer bay (CCTB) within the T&VF PB. The purpose of the CTS is to move the cask the short distance & into the CCTB along a direct path from the CRB. The CTS may be a motorized flatbed carrier on rails similar to Figure 5-1, or could be a Self Propelled Modular Transporter (SPMT) similar to Figure 5-2.

Figure 5-1 Small Transportation Cask on a Small Rail Mounted Cask Transfer Shuttle

Figure 5-2 Self Propelled Modular Transporter (SPMT) Carrying a UNF Storage Cask

5.3.2 Cask/Canister Transfer Bay

Once placed on the CTS in the CRB, the cask lid will be prepared for opening, the shield door to the CCTB will be opened and the CTS will move the cask into the CCTB. The shield door will be closed and the cask will be positioned for removal of the fuel canister. The CCTB provides a shielded hot cell, equipped with shielded observation windows, remotely controlled cameras, and cask as well as canister handling cranes. The CCTB also provides robotic manipulators and associated cask and canister handling tools to open the casks and canisters with welded or bolted lids, and to reseal them when handling operations are complete. It is assumed that the fuel will not be received as bundled fuel rods but could be received bare in transportation casks. Cask and canister gas sampling will be provided in the CCTB. Infrastructure and equipment will be provided to inert, leak test, and remove moisture from the canister by vacuum drying it prior to its return to the CSF storage location.

The fuel canister will be lifted from the cask by the 200 ton overhead crane and placed in the canister workstation on one side of the CCTB. The storage cask will be placed in a cask interim storage position on one side of the CCTB. The workstation is equipped with pan/tilt zoom color cameras, robotic manipulators and an overhead hoist on the overhead crane, gas sampling and fill services. Adjacent to the workstation is a remotely operated automated canister cutting machine (ACCM) and a remotely operated automated canister welding machine (ACWM). If the canister lid is welded, the ACCM is positioned over the canister and the canister lid or lids are cut and removed, exposing the fuel assemblies within.

A number of such ACCM and ACWM systems are available from companies such as TriTool Inc., Westinghouse, Moog and Areva Transnuclear Inc. Representative images are included in Figures 5-3 and 5-4 below.

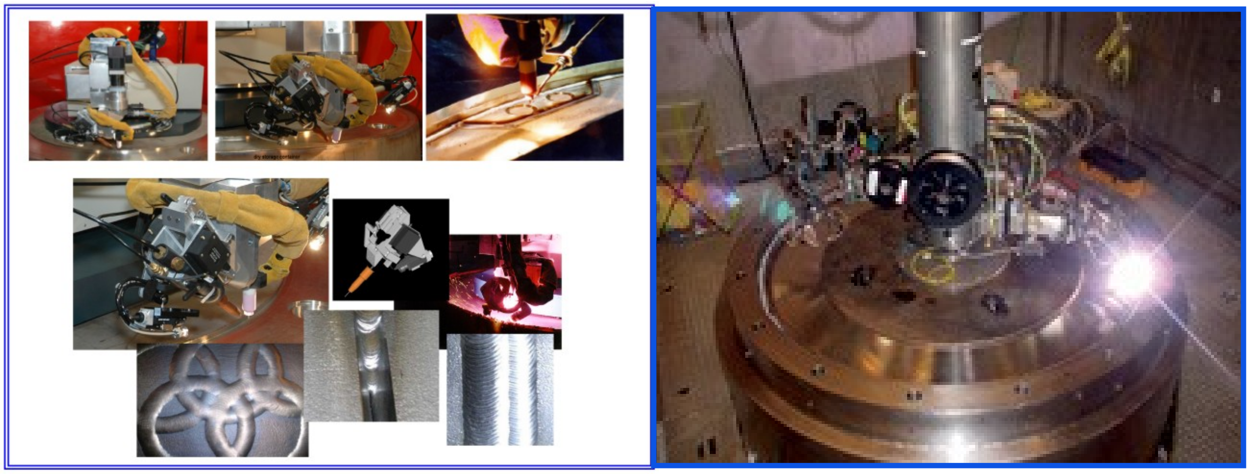


Figure 5-3 Representative Fuel Canister Automated Welding System , Welds & Fuel Canister Cutting Images

Figure 5-4 Images of Automated Welding System Mounted on Fuel Canister (Reproduced courtesy of Areva Transnuclear)

Once the canister is opened, a single fuel assembly will be lifted out of the canister and placed vertically within a metal fuel assembly support can (FASC) on a fuel assembly shuttle (FAS). The remaining fuel assemblies will remain in the canister pending return of the fuel assembly remnants, packaged in a sealed fuel assembly support can, which will be inserted in the original fuel assembly canister position or in a different canister and storage cask depending on direction from facility operations. The FASC is designed to be a little larger in dimensions than the fuel assembly and provides mechanical support during fuel assembly handling and vertical to horizontal positioning. The FASC carrying the single fuel assembly and mounted in the FAS is moved from the CCTB into the disassembly bay (DB).

5.3.3 Disassembly Bay

The DB provides four workstations with equipment to lift and rotate the FASC to a horizontal position, remove the assembly, perform visual and gamma scans, and remove the fuel assembly endplate.

Workstations and equipment will also be provided to grip and extract a fuel rod, perform a gamma scan and preliminary surface examination on a full length fuel rod, monitor and record the fuel rod extraction force, provide sampling and analysis of the fuel rod fill gas, and segment the fuel rod into small sections. The fuel segments are loaded into sample containers for transfer to the Sample Analysis bay via an analytical line transfer conveyor (ALTC). Because of the pyrophoric nature of many fuel cladding materials (e.g. Zircalloy), the DB is maintained under an argon atmosphere via a recirculating system that purifies the argon and purges contaminants. Figure 5-5 summarizes the DB work station positions.

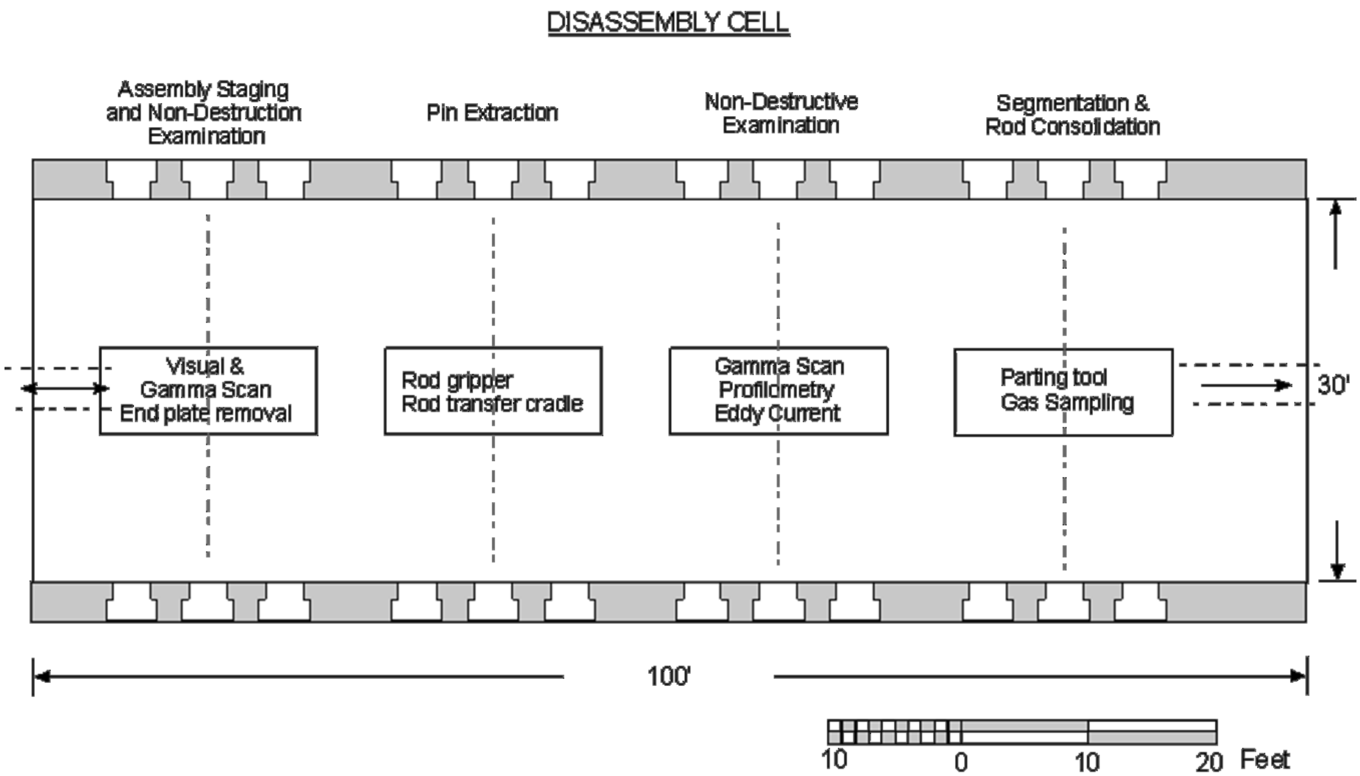


Figure 5-5 Disassembly Bay Work Station Positions

Fuel samples are placed into sample containers and programmed into the ALTC control system for transfer to their intended processing and analysis work stations. The ALTC control system automatically controls source sample and destinations along the ALTC and provides such logical and permissive controls as airlock access controls, criticality permissive controls, package traffic, ALTC intersection and directional controls, sample location tracking and sequencing, and data historian data logging with the Facility computer system. The ALTC runs from the DB longitudinally through each processing line with intersections at each analytical work station on 0' Elev. Two ALTC cross-over tunnels are provided between the two facility processing lines to allow the ALTC to carry samples between the two processing lines and associated work stations. All facility crossover tunnels are equipped with airlock entries to support entries for periodic maintenance. The ALTC can be programmed to transfer between locations on each processing line under control of the operator. The links below provide representative videos of one ALTC type system. (CTL + Click to follow Links)

http://www.youtube.com/watch?v=AY5b6DHy9CY&feature=player_embedded
http://www.youtube.com/watch?v=qrFlOECiot0&feature=player_detailpage
http://www.youtube.com/watch?v=LWneeoDypxA&feature=player_detailpage

Because the fuel samples to be removed from a fuel rod for analysis do not consume the entire fuel rod, unused remnants of the fuel rod can be segmented and placed in a fuel remnant storage can (FRSC) or cans, and sealed for subsequent placement in a canister and fuel cask for ongoing storage. As it is not immediately known if additional fuel samples may subsequently be needed to be removed from the remnant rod once downstream segment analysis is conducted, the rod remnants are placed in the FRSC and transferred to an interim FRSC lag storage position within the center of the first crossover tunnel until fuel segment analysis is completed. When segment analysis is completed the FRSC is released for return to canister and cask storage at which time the sealed FRSC is transferred back through the DB and into the CCTB where it can be placed back into the fuel canister, resealed and placed into the source storage cask for ongoing storage at the CSF or placed into another facility canister and storage cask for ongoing storage at the CSF.

Along each side of the DB processing lines are shielded observation windows with a set of robotic manipulators, similar to Figure 5-6, to allow the operators to support disassembly bay operations.

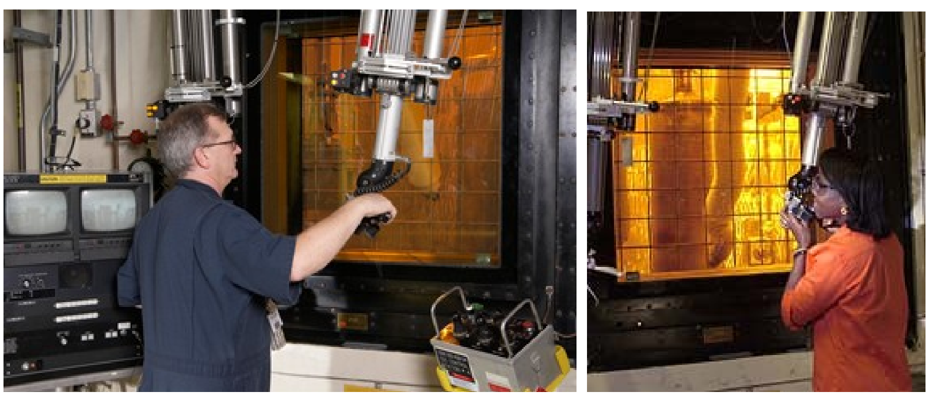


Figure 5-6 Representative Operator Robotic Manipulator Work Stations at Shielded Observation Windows

Central to the axis of the Facility and between the two DB processing lines is located the disassembly control room (DCR). There process images and data from both processing lines is presented to the DCR operators, together with data and images from other T&VF processes, via the T&VF process control system (PCS) and T&VF central computer system (CCS). As the DCR is placed central to both DB processing lines, direct observation of the process is also available via the DCR observation windows along both DB lines. Figure 5-7 shows representative DCR operator control workstations adjacent to the observation windows. The DCR also contains stairwells which communicate to the T&VF +20’ Elev. and above.

Figure 5-7 Representative DCR Operator Workstations Adjacent Observation Windows

5.3.4 Sample Analysis Bay

Downstream of the DB, fuel samples are transferred to the sample analysis (SA) bay analytical work stations where the samples undergo various physical, metallurgical, radiological and fuel characterization tests. While some analytical equipment is provided in the SA bay, a major function of the bay equipment is to extract and prepare samples that can be direct-handled safely in the Process Analysis rooms work stations located on upper elevations. Figure 5-8 shows a representative sequence of the sixteen work stations. Shielded glove box extensions may be added transverse to the analytical stations, on 0' elevation, in cases where radiation levels can be achieved which is supportive of as low as reasonably achievable (ALARA) hands on work adjacent to the main processing lines. Four representative glove box extensions are shown on the layout of 0' elevation.

Samples are extracted from fuel segments and prepared for evaluation of tensile strength, fatigue, hardness, and other mechanical properties of the cladding. Metallography and microscopy are also performed to assess surface condition and material performance following irradiation.

The SA bay includes a small voloxidation furnace to separate fuel meat from the cladding. The oxide is collected and sampled for testing; some is dissolved for wet chemistry analysis to provide composition and isotopic distribution of radionuclides. The SA bay also includes two small (400 gallon) tanks for collection of liquid waste from analytical operations, including sample preparation and purification steps.

Each workstation is equipped with an observation window and robotic manipulators to allow operators to support the handling and analytical process. Sample material can also be transferred to the +20' and + 40' levels for further processing and analysis. Samples are transferred pneumatically via transfer tube, using a dumbwaiter, or with a conveyor through the crossover tunnels to a sample receipt station in the Process Analysis Room (Figure 5-13)

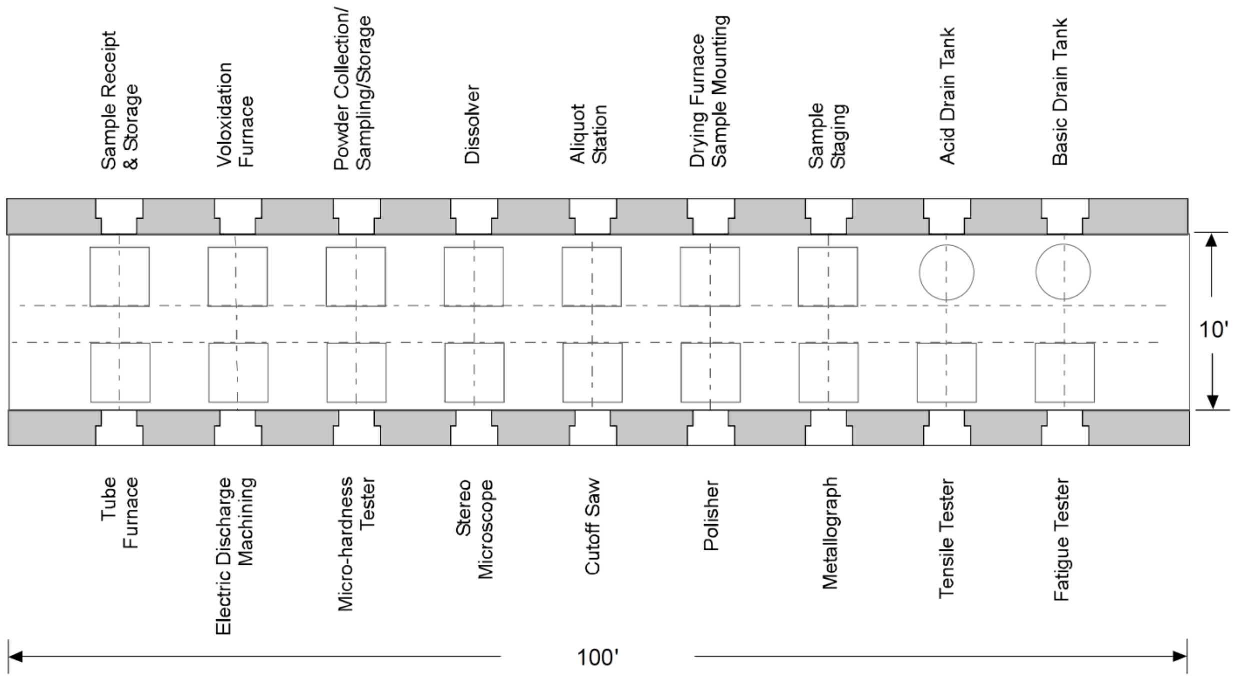


Figure 5-8 Sample Analysis Bay Analytical Work Stations Sequence

Figure 5-9 reflects an image of a representative shielded window workstation lineup with operators at the work stations robotic controls.

Figure 5-9 Representative Operators At Sample Analysis Bay Analytical Work Stations

Central to the axis of the Facility and between the two SA processing lines is located the facility main control room (MCR). There process images and data from all facility processes and both processing lines is presented to the MCR operators via the T&VF process control system (PCS) and T&VF central computer system (CCS). As the MCR is placed central to both SA processing lines, direct observation of the process is also available via the MCR observation windows along both SA lines. Figure 5-10 shows representative MCR operator control workstations with operator console PCS displays and overhead status, process, and annunciator displays.

Figure 5-10 Representative Facility MCR Operator Console, PCS Displays & Overhead Status, Process, and Annunciator Displays

5.3.5 Returns Bay

When sample analysis is completed, materials are transferred, via the ALTC, to the downstream returns bay (RB) for packaging, decontamination, and disposal. Eight workstations are provided with shielded observation windows for treatment (solidification) of liquid waste, packaging, decontamination, final inspection, rad monitoring and accountability. The last position of the RB line contains an air lock equipped with a small hoist and robotic manipulators for lifting of packages in and out of shielded containers, and placement of the container lids, that are brought into the RB airlock for transfers.

Packaged waste can be moved out of the process line via the airlock and transferred via the shielded transfer cart, to the waste handling building downstream and adjacent to the T&VF PB. Similarly, analytical instruments can be removed from the process lines via the returns bay and sent to the neighboring hot maintenance shops for maintenance or repair. The RB airlock station contains a bag in bag out port for transfer of material that can be contact handled. The RB contains a small returns bay control room (RBCR) area between the two processing lines, similar to the MCR and DCR control rooms. On the outer wall of the RBCR is a personnel and equipment elevator that communicates to all levels of the PB. This elevator can be used for operations transport and used for transfer of equipment between PB elevations after facility startup.

Material removed from the RB is transferred to the adjoining downstream maintenance and waste handling building (MWHB) via the shielded transfer cart or direct handling as needed. The MWHB is a steel framed structure containing hot and cold electrical, mechanical and instrumentation maintenance shops and a waste staging area for disposition of waste packages.

Waste can be drummed and solidified in the waste staging area in preparation for disposition. UNF debris that is still UNF can go back upstream to a canister or be packaged in the RB, shielded and reinserted in a canister through the CCTB. Waste can exit the facility via the RB. The assumed facility waste categories and how it will be managed are included in Section 5.4.

Adjacent to the MWHB are two liquid cold chemical receipt diked truck pads and chemical transfer stations together with liquid cold chemical storage tanks. A dry chemical truck unloading dock also serves an adjacent dry chemical storage structure next to the MWHB. Process gas storage tanks are provided on the opposite side of the MWHB.

5.3.6 Process Support Area (+20' Elevation)

The +20 ELEV of the T&VF PB is primarily devoted to the cranes control room, and process support functions associated with the analytical operations on the on 0' Elev. and +40' Elev. above.

The cranes control room (CCR), located central to the axis of the facility and above the DB, provides operator control and viewing capability for the cranes in the CRB, the CCTB and the DB. Shielded observation windows are also provided overlooking the CCTB and the DB operations areas. Operator control consoles provide color pan/tilt/zoom camera displays of crane operations in each area.

Mechanical equipment servicing the analytical laboratory areas include:

- Radio-hood exhaust fans
- Glove-box exhaust fans with HEPA filtration
- Vacuum blowers
- Air monitor blowers

Two chiller units providing mechanical refrigeration for chilled water supply for instrumentation and HVAC are also located in this area. Figure 5-11 provides a representative layout of the process support areas of +20' Elev.

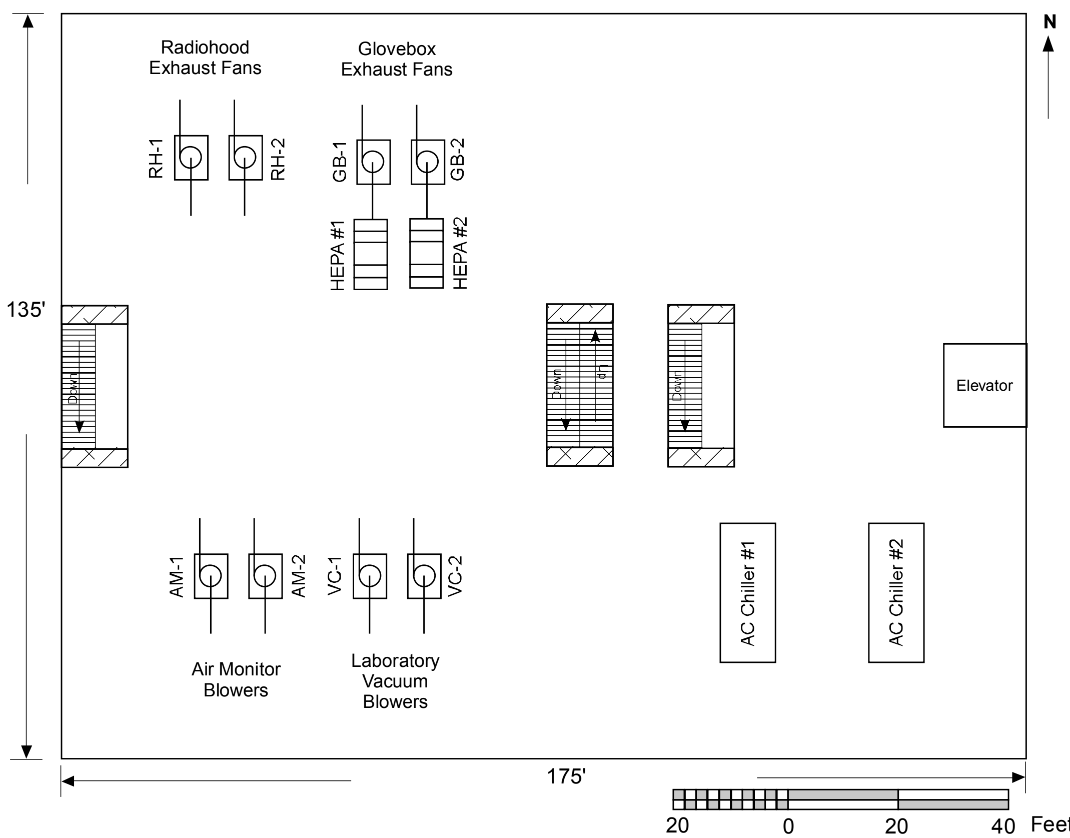
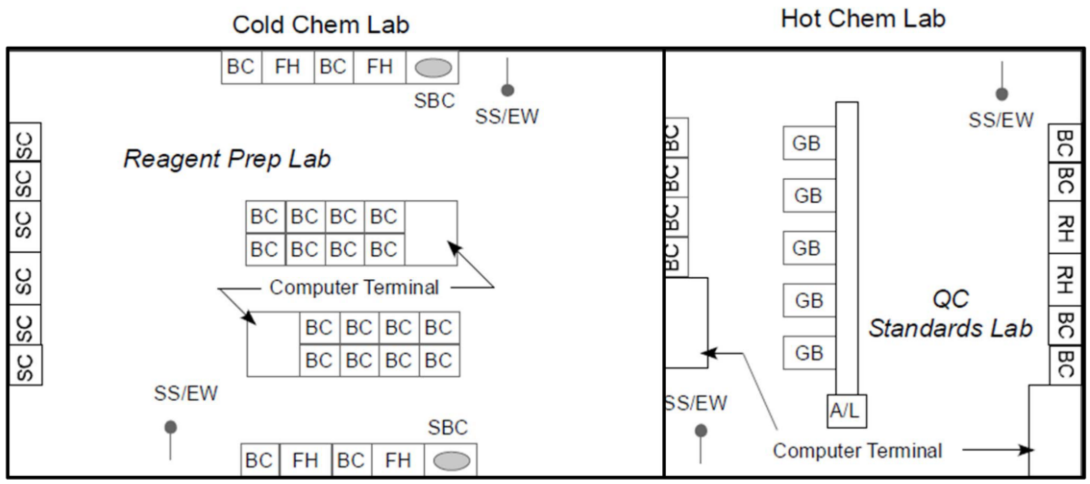


Figure 5-11 +20' Elev. Process Support Area Representative Layout

5.3.7 Chemistry Laboratories (+40' Elevation)

Hot and cold chemistry laboratories are provided on +40 Elev.to provide reagent preparation and quality control standards to support sample analyses. These operations are radiologically clean or involve trace levels of radionuclides, and can be handled in chemical hoods or glove-boxes with minimal radiation shielding. Figure 5-12 provides a representative layout of the hot and cold chemistry labs reflecting glove-box and exhaust hood workstations.



{FH=Fume Hood; BC=Base Cabinet; SC=Storage Cabinet; SBC=Sink Base Cabinet; RH=Radio Hood; A/L=Air Lock}

Figure 5-12 +40' Elev. Hot and Cold Chemistry Laboratory Representative Layout

5.3.8 Process Analysis Room #1 (+40' Elevation)

A process analysis area is included on +40' Elev. with dedicated work stations for sample receipts, un-packaging and glove box contact handling and sample analysis. Figure 5-13 provides a representative layout of this analytical area.

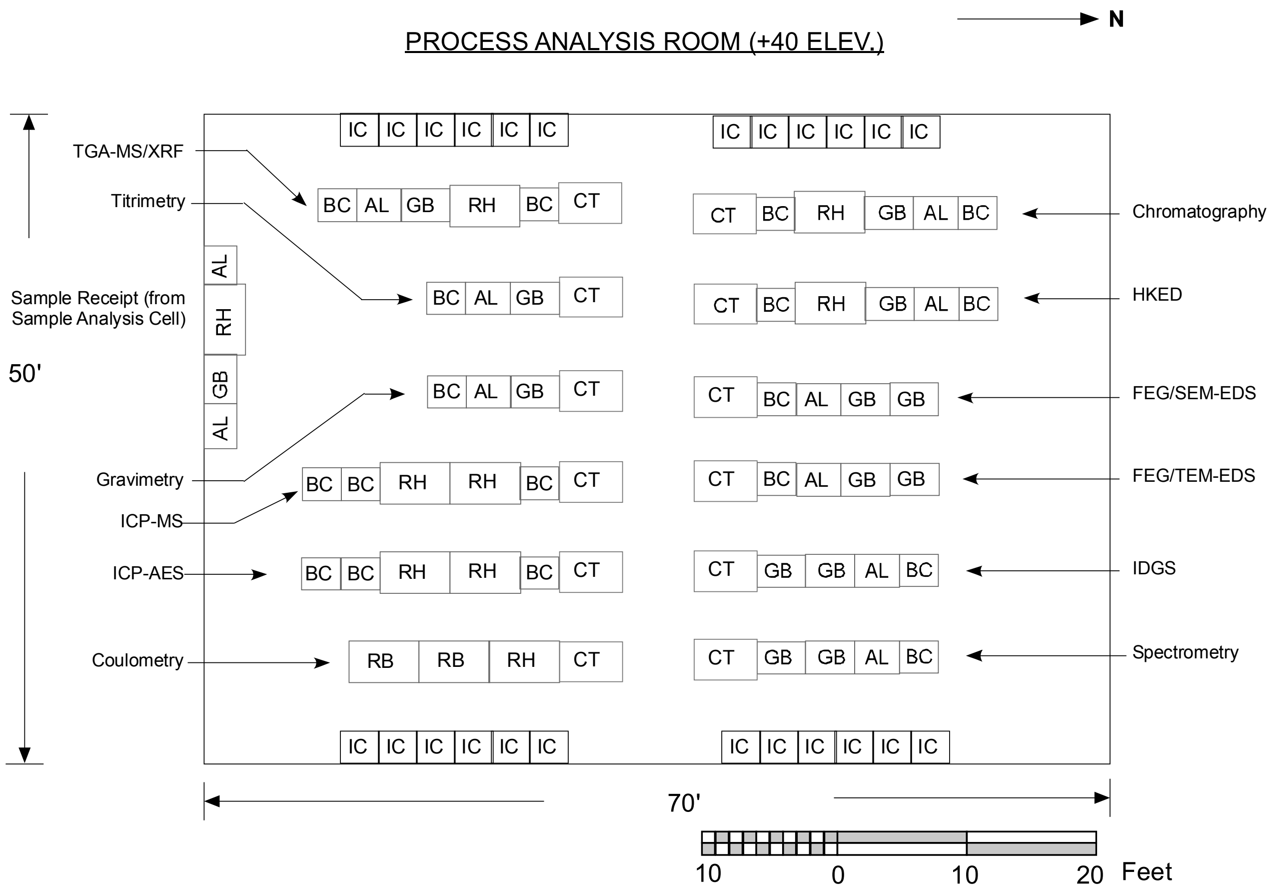
Samples are received from the SA bay in a shielded glove-box, where they are unpackaged for distribution to the individual stations for analysis. Transfer between the Sample Receipt area and the workstations are made via transfer cart; radiation shielding is provided for the sample, if required.

The workstations are configured to allow off-loading of the transfer cart, introduction of the sample to a hood or glove-box for additional conditioning, placement of the sample in the instrument. Most instruments are contained in hood enclosures to allow access to all sides. Work stations for operations requiring wet chemistry for sample preparation or analysis are provided with drain lines (acidic or basic) for waste disposal; liquid waste collection tanks are provided in the Sample Analysis bay (Figure 5-8).

Analyses performed in this area include:

- Thermogravimetric-Mass Spectrometry/X-ray Fluorescence
- Titrimetry
- Gravimetry
- Inductively Coupled Plasma Mass Spectometry

- Inductively Coupled Plasma Atomic Emission Spectrometry
- Coulometry
- Chromatography
- Hybrid K-Edge Densitometry
- Scanning Electron Microscopy
- Transmission Elecetron Microscopy
- Isotope Dilutuion Gamma Spectrometry



{AL = Airlock, BC=Base Cabinet; CT= Computer Table, GB= Glove-box, IC = Instrument Cabinet, SC=Storage Cabinet; SBC=Sink Base Cabinet; RB=, RH=Radio Hood; }

Figure 5-13 +40' Elev. Process Analysis Room #1

5.3.9 Process Analysis Room #2 (Count Room, +40' Elevation)

Process Analysis Room #2 provides equipment for alpha and gamma spectroscopy, neutron counting, and calorimetry. Samples are prepared for counting at workstations in Process Analysis Room #1, then delivered to the Count Room for analysis. Information obtained from these instruments includes uranium and plutonium content, isotopic distribution, and radionuclide content of fuel materials.

Figure 5-14 provides a schematic layout of the Count Room equipment; a large (1,000 liter) tank is provided for bulk storage of liquid nitrogen needed for instrument detector cooling.

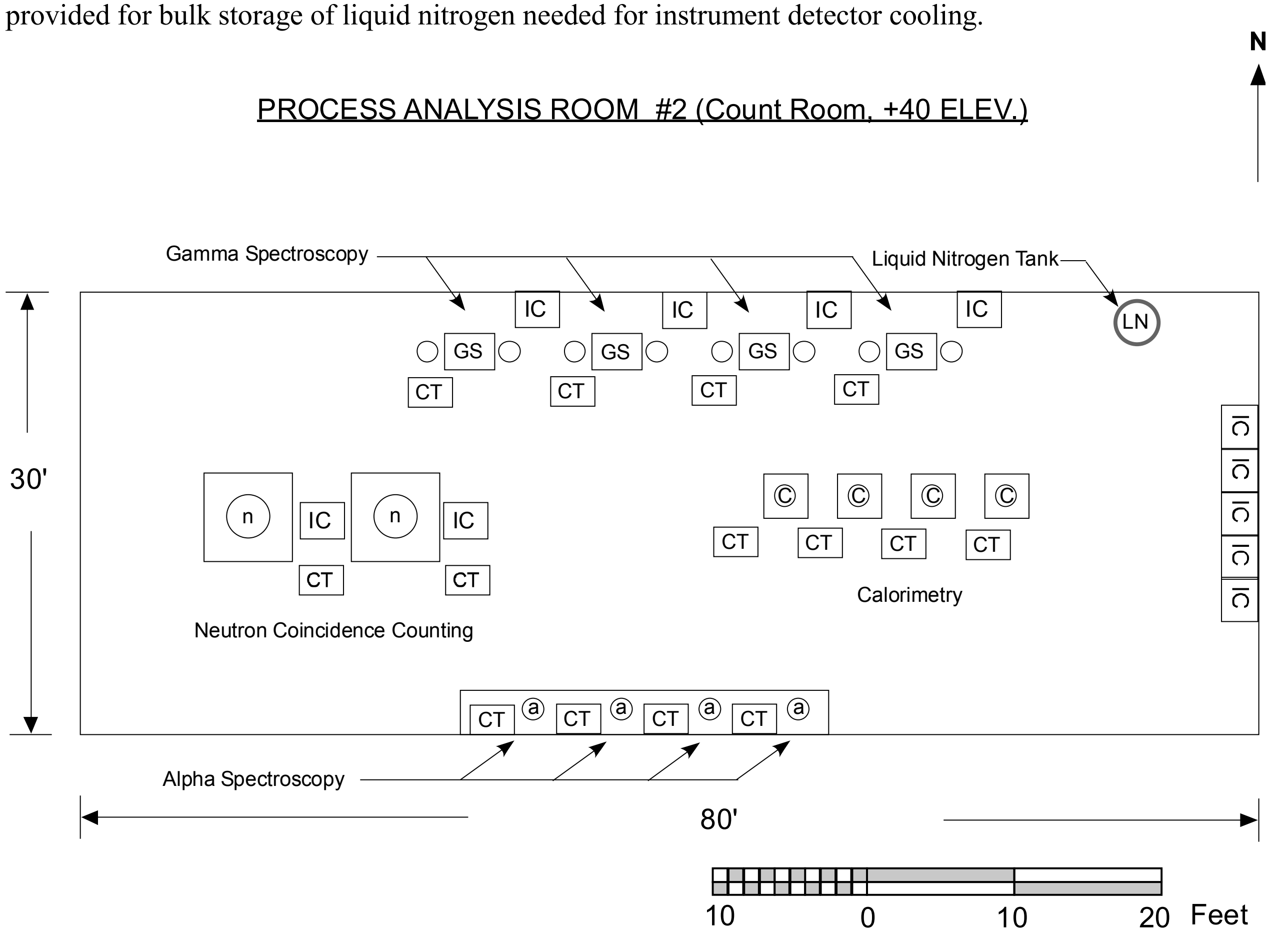


Figure 5-14 +40’ Elev. Process Analysis Room #2

5.3.10 Radiological Control Operations (+40’ Elevation)

T&VF PB +40’ Elev. also provides a Rad-con operations area with workstations for radiological testing and sample analysis, and segregated areas for the facility radiological monitoring systems. These monitoring systems include area radiation (gamma) and continuous alpha air monitoring, tied to a central computer room providing historical trending, as well as continuous readout and notification of high radiation, high rate-of-rise, instrument failure and other conditions in the facility.

5.3.11 Electrical Supply (+60’ Elevation)

T&VF PB +60’ Elev. houses normal power and redundant, segregated electrical power distribution system equipment and the principal mechanical ventilation system equipment, instrument air and process gas for the facility. Two trains of safety related electrical distribution switchgear are provided together with 125 volt DC batteries, chargers and distribution panels and 120 VAC UPS panels and distribution gear. Two redundant, segregated emergency power diesel generator buildings are provided adjacent to the T&VF, on 0' Elev., together with a normal power diesel generator to provide backup power under loss of power supplies to the facility.

5.3.12 HVAC (+60' Elevation)

Two redundant and segregated trains of mechanical ventilation exhaust fans and HEPA filter systems provide facility exhaust air flow to the facility stack where environmental monitoring is provided on facility emissions. Facility ventilation is arranged to provide air flow from clean areas to areas of greater contamination. A Process Vessel Ventilation (PVV) system maintains process lines, glove-boxes, and process vessels at a slight negative pressure relative to surrounding areas to help control contamination flow from clean areas to areas of higher potential contamination.

5.3.13 Mockup Facility

Connected to the T&VF PB is a steel framed T&VF Mock Up (MU) Facility which provides the infrastructure for 1) replicating key systems hardware present along one of the main processing lines including the fuel cask and canister opening bay; 2) the fuel assembly disassembly bay containing fuel assembly handling; 3) for fuel rod extraction & examination; 4) rod segmenting and fuel sample segments handling stations; 4) the transfer conveyor system for delivery to designated analytical work stations. In order to simulate actual physical conditions which might be needed for new technology or revised operations configurations over the life of the facility, the MU Facility will also accommodate up to 10 or more of the 20 work stations positions which exist in the actual T&VF radioactive operations processing line.

One processing line of the T&VF PB 0' Elev. and the +20' Elev. is represented in whole or in part on the first two floors of the MU facility, with the upper two floors (+ 40' and +60 Elev.) of the MU facility providing administrative floor and office space for the T&VF including operations, rad-con, security and technical & facility support staff offices, document rooms, technical library, meeting rooms, break rooms and rest room space. The axis of the MU facility is aligned parallel to the PB, and connected via a corridor along its length. The corridor provides access between the PB and the MU facility on all levels, thus connecting operations areas to support and administrative areas for the facility.

6. Assumptions

Below are the major facility assumptions.

Assumption Number	Assumption
1.0	**All safety systems are provided as redundant train systems designed to single failure criteria and able to withstand natural phenomena hazards commensurate with their safety function (TBV).** *Basis:* Facility and SSCs safety functions have not been determined.

Assumption Number	Assumption
2.0	**ES&H, S&S, and Emergency Protection/Response infrastructure and equipment will be excluded from the cost of the TV&F. They will be included in the CSF total estimated cost.** *Basis:* Program Requirement.
3.0	**Fire suppression (protection) safety related elements will be provided with a redundant fast acting gaseous fire detection and suppression system.** *Basis:* Facility and SSCs safety functions have not been determined.
4.0	**Radiation shielding requirements and the effects on waste emissions shall be based on a standard fuel burn-up of 60 GWd/MTHM (TBV).** Basis: Burn-up is a primary factor used to determine source terms for shielding requirements and effects on wastes and emissions Basis: 60 GWd/MTHM also supports DOE-NE near-term objective within the R&D scope to address the existing used fuel discharged from existing commercial LWRs. Under this objective, there is a high priority to investigate extended storage and transportation of high burn-up fuels (≥ 45 GWd/MTHM) since reactor operations are moving to higher burn-ups and there is limited understanding of the impacts of higher burn-ups on long-term storage.
5.0	**LLW will be disposed at one of DOE's waste disposal facilities or at a commercial LLW disposal facility (TBV).** *Basis:* LLW generated by the T&VF Process Support Systems must meet DOE disposal requirements. *Basis:* LLW will be transported offsite per DOT regulations 49 CFR 173.
6.0	**GTCC waste packages will be stored at the CSF. No disposal path has been defined.** *Basis:* GTCC waste **(TBV)** may be generated by the T&VF and shall be prepared for storage at the CSF per 10 CFR 72.
7.0	**UNF debris packages will be stored at the CSF. No disposal path has been defined** *Basis:* UNF debris will be generated by the T&VF and shall be prepared for storage at the CSF per 10 CFR 72.
8.0	**UNF material will not be stored at the T&V Facility** *Basis:* Any temporary staging of the UNF material either prior to, during, or after examinations of the assemblies, rods, and segments is considered to be part of the process.

7. Major Equipment List

Below is a list of major equipment associated with the T&VF UNF storage cask pad located at the CSF. This list does not include equipment needed to handle and/or transfer the storage and instrumented casks. The UNF storage casks are excluded from the list because they will be included with the CSF equipment list.

- A UNF storage cask pad approximately 3 feet deep, 67 feet long, and 30 feet wide.
- Storage pad monitoring and inspection equipment (TBD)
- 1-3 Instrumented Storage Casks.

Below is a list of equipment associated with the systems and components needed to conduct the testing and validation processes described in Section 5.3. This list does not include equipment needed to handle and/or transfer the casks, canisters, assemblies, and rods.

Equipment List
Inert tube furnaces (2, to 400° C)
Indexing feeder/guide system, programmable
Gamma scanner (HPGe)
Profilometer, Collimator, Eddy-current test equipment
Tube puncture/gas analyzer/vacuum system
ICP-MS
Parting tool, feeder, conveyor system
Rod recovery and disposal chamber
Small shielded waste containers
Remote cameras w/monitoring station
Electric Discharge Machining system
Micro-hardness tester
Stereo-microscope
Cutoff saw
Sample mounting equipment
Polisher, automatic
Metallograph
FEG SEM w/EDS (1 table-top, 1 standard)
FEG TEM w/EDS
Focused ion beam instrument for TEM specimen preparation
Laser etching machine
TEM polishing equipment
Tensile testers, screw-driven; 3 w/furnaces, 1 w/autoclave, & all controls
Fatigue test machine

8. Cost Study

A team of subject matter experts used Savannah River Site models to develop costs based on the conceptual design scope described in sections 4.0 and 5.0. Application of these cost models resulted in an estimated cost of $1.2 Billion.

Other project costs (e.g., project support, design authority, start-up testing, and operations training, etc.) were not included but are expected to be ~30% of the Total Estimated Cost (TEC). Other project costs (OPC) will be dependent upon contracting strategy and costing practices associated with the facility owner and location.

Based on uncertainties associated with constructing a complex, first of a kind, hardened, high radiation facility, the team assumed a contractor's contingency range of 20% to 50% and a risk contingency range of 0% to 25%. Application of the combined contingencies (20% to 75%) resulted in a ROM TEC of between $1.5 and $2.2 Billion. Establishing a high and low range using the contingency ranges is normal practice for a ROM case study. Table S-1 summarizes the T&VF ROM TEC.

Table 8-1 T&VF Total Estimated Cost

	Contingency		**Dual Process Lines and Mock-up Facility Estimated Cost ($ Millions)**	
	Low	High	Low	High
Scope Baseline	N/A	N/A	$1,232	$1,232
Contractor Contingency	20%	50%	$246	$616
Risk Contingency	0%	25%	$0	$308
Total Estimated Cost	**N/A**	**N/A**	**$1,478**	**$2,156**

Dual processing lines and a mock-up facility were included in the conceptual design to reduce the risk associated with operating a complex first of a kind facility for a minimum of 40 years which was assumed to be the life of the facility. As a sensitivity check on these major cost drivers, the team completed parametric cost analyses for the two design variations described below and summarized in Table S-2.

Design Variation A: Dual processing lines with-out a mock- up facility - The baseline TEC would decrease by ~$150 to $220 Million. The consequence of eliminating the mock-up facility would be reductions in the facility's ability to adjust to system and/or operating changes in a non -radioactive environment.

Design Variation B: Single process line with mock-up facility - The baseline TEC would decrease by ~ $530 to $780 Million. The consequence of eliminating one of the dual processing lines would be the reduction in the ability to continue to operate while major systems, structures, or components are being maintained, during facility outages, or if process upset conditions occur.

Table 8-2 Facility Design Variations TEC

Facility Design Variations	Total Estimated Cost ($ Millions)	
	Low Cost	High Cost
Dual Process Lines and Mock-up Facility (Estimate Baseline Rounded)	$1,480	$2,160
Dual Process Lines with-out Mock-up Facility	$1,330	$1,940
Single Process Line with Mock-up Facility	$950	$1,380

9. Benefits

The T&VF will benefit other DOE-NE missions by providing facilities that will have the capability to 1) inspect and examine UNF and/or High Level Waste for commercial utilities, NRC, and DOE; 2) support R&D for Small Modular Reactors and the front end of the fuel cycle; and 3) support other fuel cycle research and development activities which require radioactive materials from commercial power operations.

10. References

1. *Used Nuclear Fuel Storage and Transportation Research, Development ,and Demonstration Plan (DOE 2012a)*
2. *Used Fuel Research and Development Extended Used Fuel Storage R&D Functions and Requirements (DOE 2012b).*

11. Appendix A – Facility Lay-out Drawings

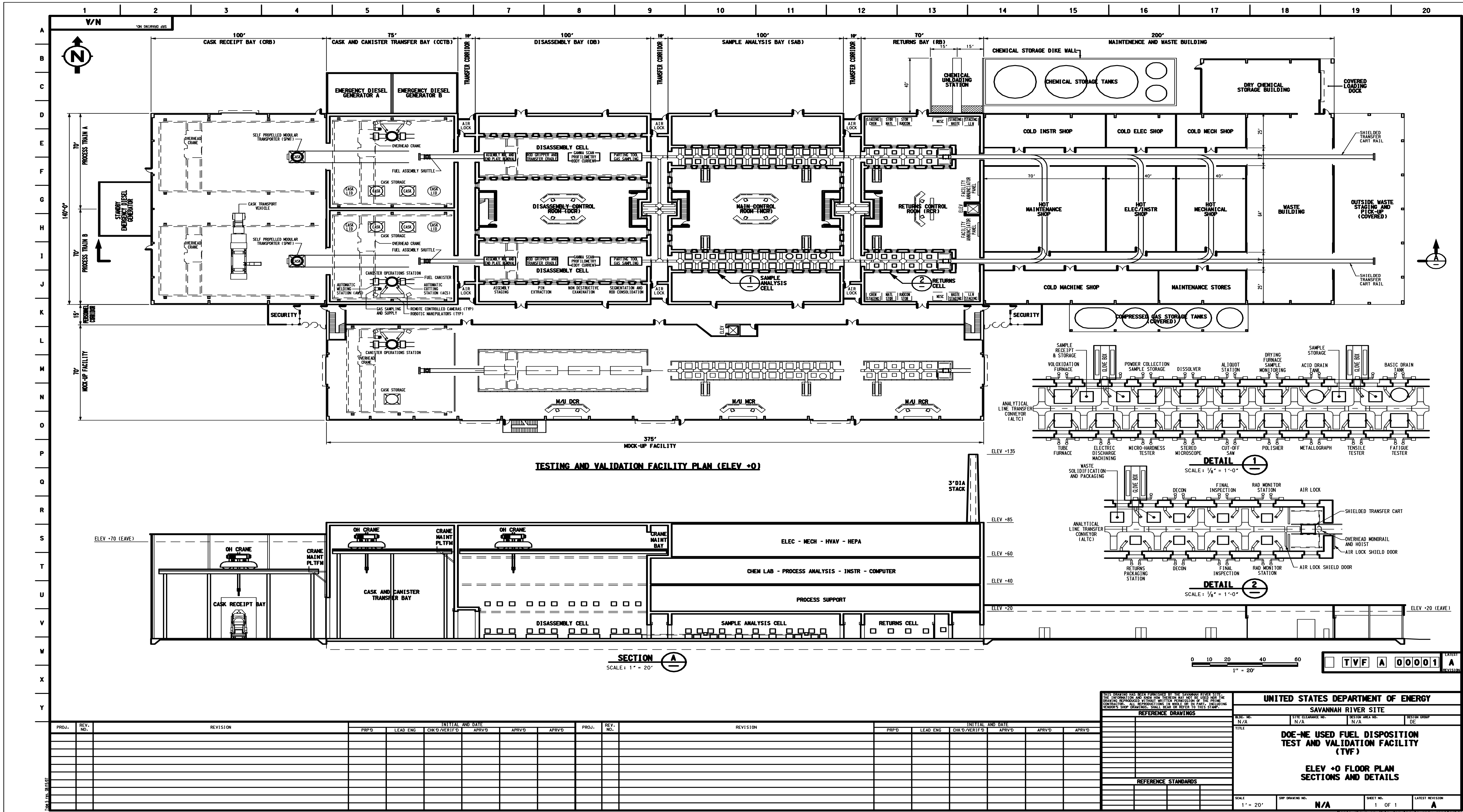


Figure A-1 Test and Validation Facility Elevation 0 Feet

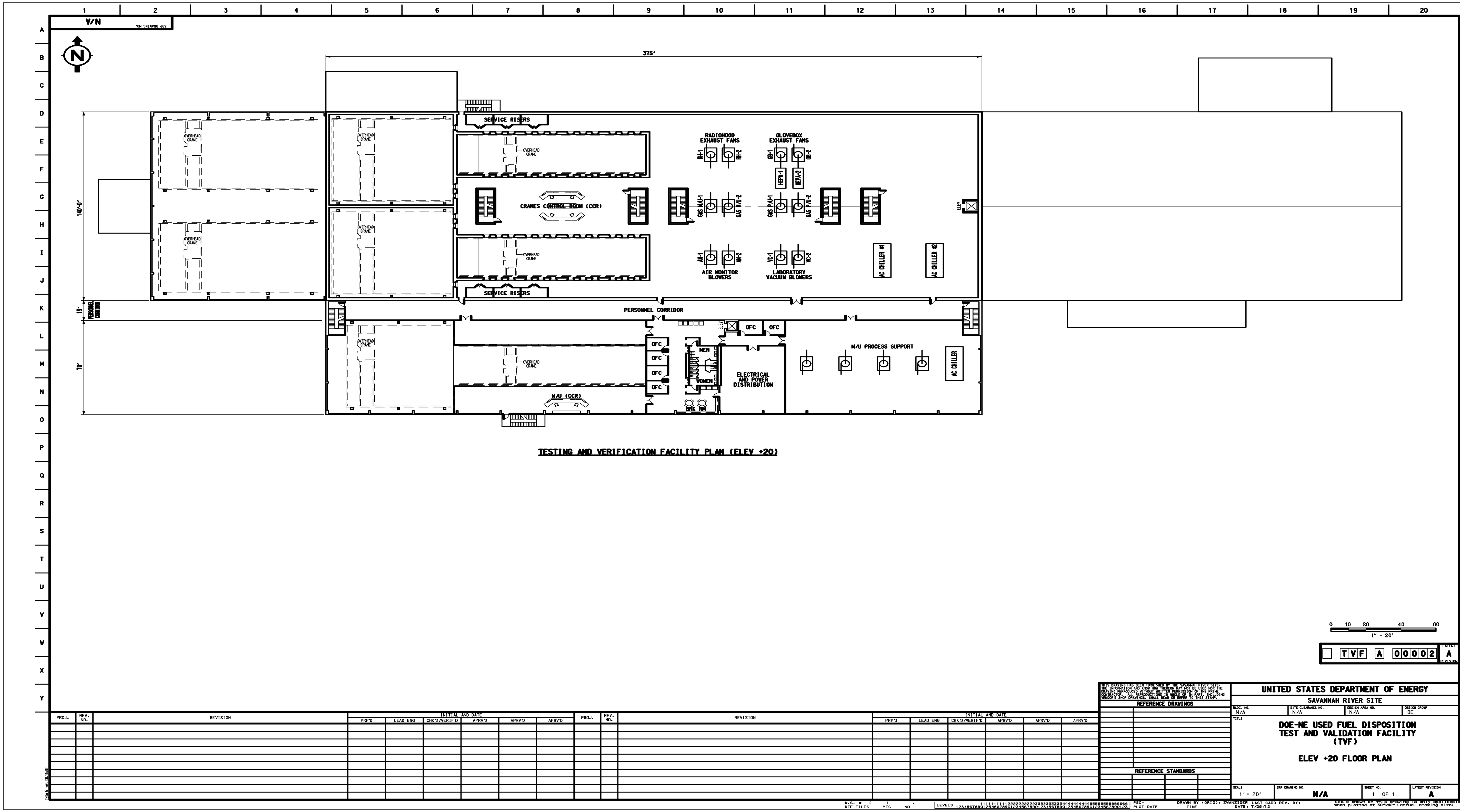


Figure A-2 Test and Validation Facility Elevation + 20 Feet

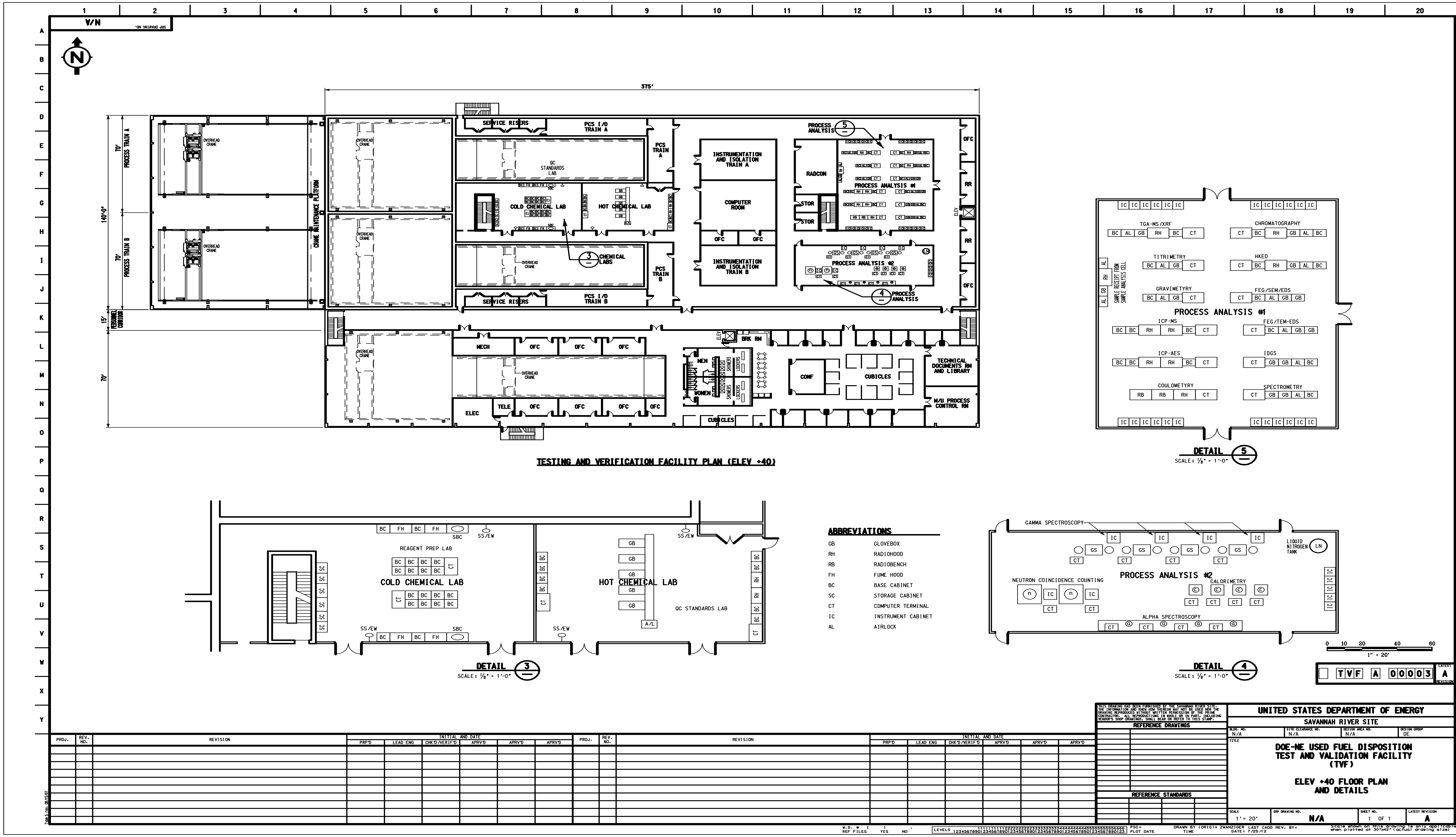


Figure A-3 Test and Validation Facility Elevation + 40 Feet

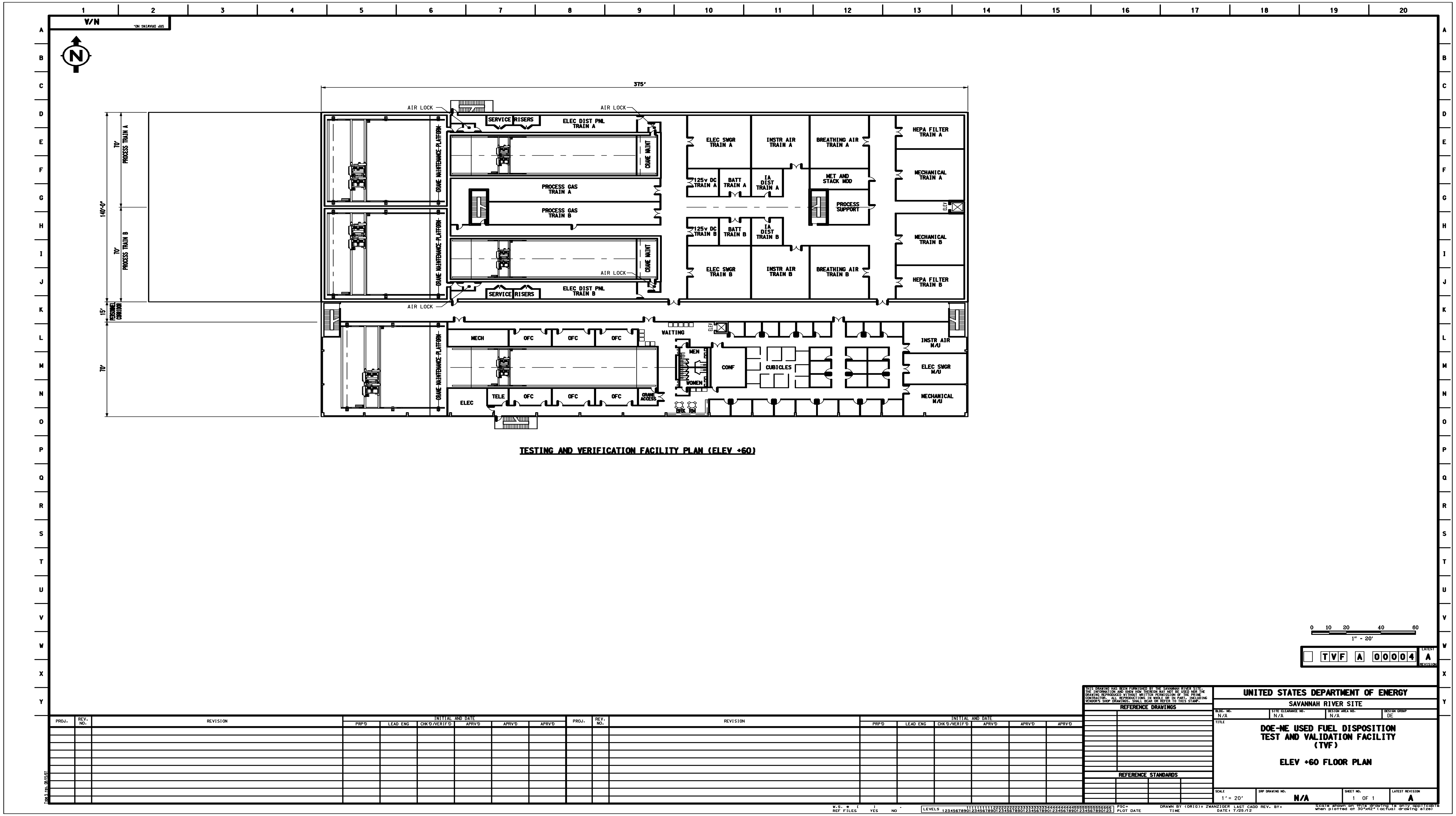


Figure A-4 Test and Validation Facility Elevation + 60 Feet