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12.12.1965 1-2 (11. PK.)

Contract No. DE-AC07-86ID12651

PROTOTYPICAL ROD CONSOLIDATION
DEMONSTRATION PROJECT
PHASE III FINAL REPORT
VOLUME I OF IV
COLD CHECKOUT TEST REPORT
BOOK 1 OF 9

Submitted to
DEPARTMENT OF ENERGY
IDAHO FIELD OFFICE
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Submitted by
NUS
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DOE PROTOTYPICAL ROD CONSOLIDATION PROJECT PHASE III FINAL REPORT
PREFACE

The Phase III Final Report for the Prototypical Rod Consolidation Demonstration Project is divided into four volumes as described below:

- Volume I - Cold Checkout Test Report (9 books)
- Volume II - Design Description (2 books)
- Volume III - Drawings (Supplied separately per contract as
not blue line copies, reproducible mylars
included and 35mm aperture cards)
- Volume IV - Operations and Maintenance Manual (5 books)

Each book of Volumes I, II, and IV contain the Table of Contents for all books of the volume.

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DOE PROTOTYPICAL ROD CONSOLIDATION PROJECT PHASE III FINAL REPORT

VOLUME I

TEST REPORT

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1.0 INTRODUCTION

The objective of Phase III of the Prototypical Rod Consolidation Demonstration Project (PRCDP) was to procure, fabricate, assemble, and test the Prototypical Rod Consolidation System as described in the NUS Phase II Final Design Report. This effort required providing the materials, components, and fabricated parts which makes up all of the system equipment. In addition, it included the assembly, installation, and setup of this equipment at the Cold Test Facility. During the Phase III effort the system was tested on a component, subsystem, and system level.

This volume discusses the PRCPD Phase III Test Program that was conducted by the HALLIBURTON NUS Environmental Corporation under contract DE-AC07-86ID12651 with the United States Department of Energy. Volume II of this report will provide a detailed design description of the Prototypical Rod Consolidation System as it was designed and installed at the Phase III Cold Test Facility located in Pittsburgh, Pennsylvania. Volume III contains the as-built drawings that were prepared by HALLIBURTON NUS to fabricate and install the Prototypical Rod Consolidation System in the Cold Test Facility. Volume IV provides the Operating and Maintenance Manual for the Prototypical Rod Consolidation System that was installed at the Cold Test Facility.

2.0 BACKGROUND

2.1 PROTOTYPICAL ROD CONSOLIDATION DEMONSTRATION PROJECT

The U.S. Government has determined that fuel rod consolidation equipment may be needed in its program to establish long term disposal of spent nuclear fuel. This equipment will separate the fuel rods from the non-fuel-bearing components, consolidate the rods into a tightly packed array, and load them into a storage canister. This equipment is to operate in a dry environment within any of the proposed geologic repository facilities or the Monitored Retrievable Storage (MRS) facility. To this end, a four-phased program was established to develop a licensable design which will be used at a repository or MRS facility. The four phases of the program are listed below:

Phase I: Preliminary design of dry nuclear fuel rod consolidation equipment, secondary waste handling equipment, non fuel bearing component handling equipment, consolidated fuel canister loading canister closure system, and decontamination and inspection systems.

Phase II: Final design of the equipment developed in Phase I for installation in the Test Area North (TAN) Hot Shop at the Idaho National Engineering Laboratory (INEL).

Phase III: Fabrication, assembly, and functional checkout of the equipment developed in Phase II, cold checkout of the system utilizing mock-up fuel assemblies and packaging and shipping of the equipment to the INEL-TAN facility in Idaho.

Phase IV: Provision of assistance and consulting during the installation and performance of the consolidation demonstration (using actual commercial reactor spent fuel) performed by others.

NUS Corporation participated in Phases I and II of the program and was selected by DOE to perform the Phase III effort. The HALLIBURTON NUS effort for all three phases was covered under DOE contract DE-AC07-86ID12651.

The award of the Phase III effort was made by DOE on May 30, 1989, for an activated 30-month period. After two contract extensions, the project was completed on May 31, 1993.

In May 1992 the originally planned comprehensive test program

was modified to reduce the test program scope due to budget constraints. The refocused test program concentrated on testing the operation and throughput of the key processing equipment to prove the basic design concepts and determine any recommendations for future designs. Testing of such features as remote maintainability and recovery from off-normal events was canceled. In May 1992 DOE advised that the Phase IV program was to be canceled and that the installed equipment was going to be excessed after the Phase III testing was completed.

Contractual changes were negotiated in October 1992 to substitute the refocused test program and to modify some of the design, fabrication, and installation activities that were not necessary for the refocused test program.

2.2 ROD CONSOLIDATION SYSTEM DESCRIPTION

The descriptions contained herein reflect the equipment and systems that were installed in the Phase III Test Facility (Ref. Dwgs. 9315-M-0080, 0081, 0082). Modifications made to the originally planned system installation resulting from the refocused test program are discussed. A more detailed technical description of each system and subsystem can be found in the individual appendices of this volume which describe the system operations testing performed on the various systems.

Appendix I-4.23, which discusses the Integrated Systems Testing for normal processing of the Westinghouse 17X17 (W 17x17) fuel assemblies, contains a step-by-step description of that processing operation.

2.2.1 Process Description

The Rod Consolidation System consists of the automated equipment designed to remove fuel rods from multiple assemblies of the same type and manufacturer, and consolidate them into either a square or round configuration. The system has been designed to be contained in a 55' x 20' x 31'-0" cell which has been divided into two separate areas. The contaminated area contains all the equipment for handling and processing fuel assemblies and fuel rods. The clean area contains all the equipment for handling and processing canistered fuel rods and canistered non-fuel-bearing components (NFBC).

The design approach is based upon an automated system for the remote consolidation processing of commercial spent nuclear fuel. A maximum fuel rod packing density into any of two different

canister geometries is achieved by use of a specific geometry hopper and positive mechanical positioning of each fuel rod. A horizontal extraction, compaction, and fuel rod loading system utilizes mechanical guides and gravity to sort, place, and configure the fuel rods into a closely packed triangular array. Mock-ups of four types of commercial LWR spent fuel were provided by the government to be processed by the system during the test program. When it was decided to refocus the test program, only the W 17x17 fuel assemblies were selected for the normal Integrated Systems Testing.

The system has been designed to meet a heavy metal processing requirement of 750 metric tons per year. To meet the system processing requirement, the system process employs parallel and series motions to minimize equipment idle time. Four main process loops are in operation at any time throughout the consolidation process. The four main processes are as follows:

- o Fuel assembly preparation
- o Fuel rod consolidation
- o Fuel-bearing component canister processing
- o Non-fuel-bearing component canister processing

A brief description of each of the above main processes is provided in the following section.

2.2.1.1 Fuel Assembly Preparation (WBS 1.3.1)

Spent fuel assemblies are vertically loaded by a crane into the Downender located next to the Fuel Assembly Storage Rack. The fuel assembly is inspected for gross physical damage by a camera inspection system as it is lowered into the cell. The fuel assembly is then rotated by the Downender to the horizontal position where it can be picked up and transported by the Robotic Bridge Transporter (RBT) with the appropriate Fuel Assembly Handling Fixture (FAHF) to the Fuel Assembly Storage Rack and stored horizontally. This sequence of operation continues until the storage rack has been loaded with fuel. Once all fuel is loaded, the consolidation process is initiated. A single fuel assembly is horizontally transferred to the Cutting Station by the RBT with the appropriate FAHF. The upper end fitting (PWR) or upper and lower end fittings (BWR) are removed from the fuel assemblies at the Cutting Station. The upper end fittings are removed from PWR and BWR assemblies using the various Upper Cutting System tools. The lower end fittings are removed from BWR fuels using the Lower Cutting System (bandsaw). All of the Upper Cutting System fixtures are modules bolted to the system slides. Once the end fittings have been removed, the fuel assembly is transferred from the Cutting Station to the Clamping Table or Staging Station

by the RBT with the appropriate FAHF. These operations continue in parallel with the rod extraction and loading operations. BWR fuel rod hold down springs are removed from those assemblies at the Cutting Station by a Spring Removal System and ejected into a debris catch pan for periodic removal from the cell.

2.2.1.2 Fuel Rod Consolidation (WBS 1.3.2)

When the previous rod extraction cycle has been completed and the fuel assembly skeleton is removed, the next group of assemblies (two PWR or four BWR) is transferred, one at a time, onto the Clamping Table by the RBT. Removable supports and clamps are provided to secure the assemblies for rod extraction operations. All PWR assemblies are clamped at the lower end fitting to counteract rod pulling forces and restrained or positioned at the upper end to ensure alignment with the pull heads. All BWR assemblies are secured at three positions along the length by a spring mechanism to counteract rod pulling forces and positioned at the upper end to ensure alignment of pull heads. In addition, pads and rails are provided to support all assemblies along their length. Once the assemblies are in position on the Clamping Table, rod extraction operations begin. Multiple fuel rod withdrawal is accomplished by pulling single rows from two PWR or four BWR fuel assemblies at one time by the Rod Extraction System. The top row of rods is gripped and withdrawn simultaneously onto the Rod Consolidation Table. The withdrawn fuel rods are then positively captured and horizontally transferred by the Rod Compaction System to a temporary storage area. The temporary storage area provides vertical restraint and maintains the fuel rods in a compact side-by-side array. When one canister layer of rods is contained within this temporary storage area (dependent on fuel rod diameter), a gate is lifted and the rods are pulled onto a slip sheet located above the Rod Loading System hopper. As the rods are transferred to the slip sheet, they are counted and the distance that the rods move is measured to ensure that the correct number of rods is transferred. Then the gate is closed. The slip sheet is then withdrawn and allows the captured fuel rods to drop onto a stacking plate within the hopper. The hopper stacking plate indexes down for the next row and the slip sheet is repositioned. The rod loading process continues if a sufficient quantity of rods are available within the Compaction System for the next full row of consolidated rods. While the Rod Compaction System and Rod Loading System are processing the removed fuel rods, the fuel assemblies on the Clamping Table are indexed one row up and the Rod Extraction System returns to pull the second row of fuel rods. The extraction, compaction, and loading of fuel rods repeats until all of the rods have been removed from the fuel assemblies and loaded into a specific geometry hopper. The system is designed to consolidate fuel assemblies with a broad range of parameters

(quantity of rods, array, and rod diameter). For example, two Babcock and Wilcox 15x15 PWR fuel assemblies will be consolidated into an 8.5 inch x 8.5 inch square canister with a resulting 22 rows of 0.430 inch diameter fuel rods. Thus, the Extraction System will experience 15 rod extraction cycles and the loading system will go through 22 rod loading cycles. The rod storage area has been sized to contain a maximum of two rod extractions worth of fuel rods for the extraction and loading cycles to proceed on a timely basis.

Upon complete loading of the hopper with all of the fuel-bearing rods, the closely packed array of rods is pushed into a fuel canister of like geometry by means of a rod pusher. This completes the fuel rod consolidation cycle with exception of the removal of the NFBC skeletons.

Upon complete removal of all fuel-bearing rods from the spent fuel assemblies on the Clamping Table, the RBT with the appropriate FAHF lifts, transfers, and deposits each fuel assembly skeleton onto the NFBC Loading Station one at a time. When the NFBC Loader has been loaded with either two PWR or three BWR skeletons, the system loads the skeletons into a 20 inch square NFBC canister. The PWR NFBC canisters contain four 10 inch square compartments (2 x 2 array) while the BWR NFBC canisters contain nine 6.67 inch square compartments (3 x 3 array). The skeleton loading tray indexes to each level to allow full loading of the NFBC canister with four PWR skeletons or nine BWR skeletons. Thus, each NFBC canister is fully loaded every other consolidation cycle. This completes the NFBC cycle of the Fuel Assembly Consolidation process. At this point in time, the Fuel Assembly Preparation cycle proceeds to reload the fuel Clamping Table. This process or the rod extraction commences along with processing of the fuel-bearing canister in the clean area.

2.2.1.3 Fuel-Bearing Component Canister Processing (WBS 1.3.3)

The Fuel-Bearing Component (FBC) canisters are stored vertically in the Fuel Canister Storage Racks located within the cell's clean area to minimize the potential contamination of the exterior surfaces. The fuel canister lids are attached manually as required during the test operation. The empty canisters are handled by use of a special grapple that mates with an ex-cell crane. This grapple is designed to transfer the FBC and NFBC canisters from the storage racks to the upenders and then back to the canister storage racks when they are full.

The empty fuel-bearing canister is moved from the Fuel Canister Storage Rack to the Fuel Canister Upender. The Upender clamps the canister and rotates it to the horizontal position. The canister

final position is established by guides and hard stops to accurately position the empty fuel canister opposite a transfer hole in the partition which separates the contaminated and clean areas. The canisters are always maintained within the clean area and only the opening of the canister mates with the opening to the contaminated area.

Upon transferring the consolidated fuel rod array into the fuel canister, the upender rotates the fuel canister to the vertical position and a canister lid is manually installed. The fuel canister is grappled by the crane and placed into the storage rack for later removal from the cell. Following placement of the fully loaded fuel canister into the storage rack, an empty fuel canister is transferred from the same storage rack to the fuel upender.

2.2.1.4 Non-Fuel-Bearing Component Canister (Container) Processing (WBS 1.3.4)

The NFBC container is stored vertically in a storage rack in the clean area with the canister lids in place. The empty container is moved from the storage rack to the NFBC container upender using a crane and grapple where the container is clamped in place. Once in position, the lid is manually unlatched from the container and removed. The container is then rotated to the horizontal position.

Upon completion of the NFBC container loading cycle (every other consolidation cycle), the container is rotated to a vertical position. After the container lid is manually installed and secured, the container is placed in the storage rack for later disposition.

This part of the process was not demonstrated in the Phase III Integrated System Testing.

2.2.2 Control Systems

2.2.2.1 Process Control System (WBS 1.2.1.1)

The Fuel Rod Consolidation Facility Control System is a centralized two-operator control station. The control room configuration accommodates two operator consoles and one Remotec RM-10A master control console in the primary operating area. Rack-mounted instrumentation, control, and logic equipment is housed in a separate area within the control complex. To facilitate cable routing, startup activities, and potential design changes, the operation and control cabinet areas are located on a raised floor.

Each operator console is equipped with:

- o Color graphics CRT terminal with touch-screen interface.
- o Keyboard for alphanumeric data entry and select control features.
- o Joystick control for bridge crane operations.
- o Emergency process halt control(s).
- o Surveillance equipment: CCTV manual/automatic video camera switcher; pan-tilt-zoom controls for CCTV cameras, two 9 inch monitors, and two 19 inch monitors, suspended from the ceiling; audio monitoring panel.

All aspects of remote automatic and manual control, position/performance sensing are controlled and monitored using a programmable controller.

A remote I/O processor provides the data interface between the consoles and the controlled monitored equipment. Through this interface, the consoles communicate with four-axis automation controllers; these units provide for the precision control of the fuel handling machine positioning motors, the RBT positioning motors, and other process equipment. The console also interfaces with several remote I/O racks, which provide all required discrete and analog control and monitoring functions.

The RBT utilizes four-axis automation controllers to accomplish automatic control for the trolley, bridge, telescoping tube drive, and the end-effectors' rotate, pitch, and actuate functions. Individual manual control of each of the multi-axis controllers can be accomplished (for maintenance and testing purposes) by using a control station located on the process equipment racks adjacent to the control room.

Positioning control for the RBT is accomplished using resolvers which are internal to the servo-drives to provide position feedback. However, true positioning is measured directly by external resolvers which are mounted to the drive systems.

The two auxiliary hoists on the RBT are provided with discrete control through 120 VAC output modules.

The discussion applicable to the RBT is generically applicable to the process control technique applied to the balance of the process equipment:

Balance of Equipment

Downender System
Cutting System
Staging Area and Clamping Table
Rod Extraction System
Slipsheet/Hopper/Rod Loading System
NFBC Loading System
Side Transfer and Rod Compaction System
Canister Upender and Inspection Station
Manipulator Transporter

These subsystems utilize remote I/O modules (for position sense inputs and for actuation outputs) similar to those applied for the RBT. A consistent automatic control concept is applied throughout, with the capability for assumption of manual control as required by process conditions.

2.2.2.2 Maintenance Control (WBS 1.2.1.1.2)

The process and maintenance control systems are essentially independent with the exception of shared fuel-handling functions.

To ensure a reliable interface between these systems, the control room configuration will facilitate communications between the process and maintenance operators. In addition, software-implemented interlocks (PC logic) will ensure collision avoidance and noninterference between process and maintenance equipment when operated in common work areas.

2.2.2.3 Environmental Control System (WBS 1.2.1.1.3)

The Environmental Control System consists of instrumentation and equipment to monitor the cell parameters, including temperature, pressure, and radiation. All process signals are input to the Control System for processing and display. Alarms are provided to alert the operator of any deviation from the normal operating ranges.

Three temperature sensors are installed to monitor the ambient temperature at the Fuel Storage Rack and one temperature sensor monitors the Canister Storage Rack. Temperature sensors are also located in the supply and return ventilation ducts for both the clean and contaminated areas (These sensors were not installed in the Cold Test Facility since the ventilation ducts were not installed.). The sensors in the return ducts indicate the ambient temperatures of each area. All temperature sensors are of the resistance temperature detector (RTD) type.

A noble gas monitor is provided to detect the radiation levels in

the process cell. This monitor samples the ventilation return ducts from the contaminated area downstream of the HEPA filter to detect airborne activity at the TAN facility. This provides a prompt indication of a damaged fuel rod that releases its captured gases. The monitor is located outside the process cell in the surrounding area. The radiation detectors are the high-level/accident monitoring type. (This monitor was electrically installed at the Cold Test Facility; however, there were no piping connections to the HVAC system since the HVAC system was not installed.)

2.2.2.4 Accountability Control System (WBS 1.2.1.1.4)

Accountability control is established through segmentation of the facility into Material Balance Areas, monitoring of the movement of nuclear material through these areas, and logging of these transactions into the Control System computers.

Material Balance Areas (MBAs) are logical subdivisions of the enclosure, representing discrete steps in the movement of fuel assemblies and/or fuel rods through the consolidation process (the areas are not necessarily separated by structural partitions). These areas are defined as follows:

- Fuel assembly storage area
- Downender loading area
- Cutting area
- Staging and clamping area
- Off-normal work area
- Non-fuel-bearing canister loading area
- Extraction area
- Rod compaction area
- Upender
- Fuel canister storage area (clean cell)

From these discrete process steps, adequate accountability of the processed material can be maintained by establishing the process MBAs as:

1. Fuel assembly entry area (outside enclosure)

2. Fuel assembly storage area
3. Contaminated cell process area
4. Clean cell process area
5. Clean cell fuel canister storage area
6. Fuel canister removal area (outside enclosure)

The Accountability Control System is operable from a hardware, software, and procedural standpoint when fuel-bearing assemblies are transferred into MBA-2, and until the sealed canister(s) are removed from the enclosure out of MBA-5.

Upon initial entry into MBA-2, a fuel assembly is examined at the CCTV-based inspection station for assessment of physical condition, and for determination of the assembly serial number. Following a menu-driven display at the operator station touch screen, the operator keys in the serial number, type, and annotate the physical condition of the assembly in the fields provided. As each assembly is placed into the Fuel Assembly Storage Rack, its serial number, physical condition, type, and storage rack position are stored as a single record in the accountability database. To ensure data integrity, the record is directly written to a nonvolatile mass storage device.

As each assembly is removed from the storage rack and placed into the Cutting System in preparation for the start of the process, the transition in location is automatically recorded by receipt of data from the programmable controller system. Subsequently, as each group of assemblies reaches the Clamping Table and is prepared for the rod extraction operation, the operator must respond to a process "hold point" prior to initiation of the actual pulling process. At this point, the location of the complete group of assemblies is automatically logged into the database upon operator authorization to start rod extraction. In the event of fuel rod damage prior to this phase of the process (i.e., at the Cutting Station), the damaged material is collected via operator intervention, and the collected material is accumulated in the vacuum system receptacle and/or in a broken rod canister. In the event the vacuum is used, the serial number of the affected fuel assembly is automatically recorded into an "exception" file in the database. Similarly, if material is placed into a broken rod canister, the serial number of the canister, which is measured and recorded prior to transfer of the canister to the clean cell, is added to the same "exception" file in the database.

Prior to insertion of the rods into canisters, a process "hold

point" requires that the operator record the receiving canister serial number in response to a prompt on the operator station touch screen. Upon entry of the serial number(s), the accountability database is automatically reconciled against the incoming fuel assembly data. Any stored information relevant to broken, damaged rods (use of vacuum system, serial number of broken rod canister) is automatically factored into the inventory balance calculation; the database contains pertinent data describing all of the fuel rod components for all types of fuel assembly the facility is designed to accommodate. At the time of damage to the affected rod(s), the operator is prompted to enter data into the database, such as serial number of assembly damaged and the number of rods damaged.

These data, in conjunction with the data described above, provide sufficient input for the accountability computer to determine whether an acceptable accurate material input/output balance has been achieved. An out-of-bounds alarm (warning limit) is established, such that a discrete batch (fuel assemblies in, canisters out) which does not exhibit a material balance within predetermined specifications will cause an alarm to be sounded, and a process interlock prohibits further contaminated cell operations until the cause of the inventory difference is determined and corrected or justified. The Accountability Control System, although equipped with process interlocks, is provided with override capability to allow processing to continue if justifiable. However, accountability variance reports are automatically recorded to mass storage and printed at the hard copy device.

2.2.2.5 CCTV and Audio Surveillance Systems (WBS 1.2.1.2)

A CCTV viewing system is installed to allow the operators to view the consolidation process. The system consists of CCTV cameras, monitors, and system electronics. The cameras are located to provide the following viewing zones:

- Fuel assembly loading
- Rod cutting (one each, both upper and lower ends)
- Rod clamping and pull-out area
- Rod loading area
- Fuel canister closure
- General viewing of contaminated area and clean area.

Seven of the twelve cameras are provided with remote pan, tilt and zoom control and two cameras are provided with pan and tilt control

to permit general viewing and inspection throughout the cell. The cameras are also provided with remote control of the lens focus and iris opening. In addition to the permanent cameras, each Remotec RM-10A Manipulator is provided with two viewing cameras. These cameras are also input into the process viewing system.

The system electronics consists of a signal conditioning/amplifier unit, a CPU/switching unit, camera control drive units, an alarm interface, and control stations. Each operating panel (Process Panel Nos. 1 and 2) is provided with a control station. These stations permit either operator to view any camera on any monitor. The station also permits the operators to manipulate the PTZ, focus, and iris control of those cameras which have those features. The system can be manually programmed in the fuel to automatically perform camera and/or monitor switching. The signal conditioning/amplifier unit is provided with a numeric camera identification generator. This device displays the preassigned camera number in the corner of the monitor that is being viewed. This permits the operator to readily verify the viewing status of each monitor. The system is provided with an alarm call-up interface device. This unit receives inputs from the process controller. When hold points or alarms are generated in the controller, the alarm interface device provides an automatic call-up of two cameras to be viewed to see the problem area on the two 9 inch monitors. If more than one alarm is generated concurrently, the first will be displayed and the others will be held in queue to await servicing.

All crucial operations are audio monitored. The audio monitoring system consists of five microphones, signal conditioning/amplifier units, and speakers/headphones. Microphones are installed to monitor the following areas:

- Upper end cutting
- Lower end cutting
- Rod extraction
- Rod compaction
- Rod loading

Two speakers are mounted in the control room ceiling, one above each of the operating stations. Audio monitoring can be accomplished via the overhead speakers and/or the headphones.

System electronics and amplifiers are provided to permit each operator to monitor the five operating stations listed above.

2.2.3 Waste Handling

2.2.3.1 End Fitting Disposal

During fuel assembly consolidation processing, the end fittings are removed (top end for PWR fuel and both ends for BWR fuels) and dropped into a container. These containers are located at the Cutting Systems in the contaminated area of the consolidation cell. After the end fittings are cut free from the fuel bundle, they are positioned over the containers by the respective Cutting System. The Cutting System clamps are then opened to release the end fitting to fall into the container. The Cutting Systems are then moved to their respective home positions. The RM-10A and auxiliary hoists are required to move the container to the Waste Container Transfer Fixture. Specially designed and fabricated end fitting containers were not provided for the refocused test program. A cardboard container was used for the Upper Cutting System since the actual design could not be established until some experience was gained with cutting off end fittings and the gravity fall was observed.

2.2.3.2 Fuel Crud

During fuel assembly consolidation processing, crud is generated by the handling and disassembly operations of the fuel. Two independent systems were incorporated into the design for the collection and containment of the crud. A continuous vacuuming system was added to collect crud at the Cutting Station and Clamping Table (areas of highest crud generation). In addition, a portable system is contained within the cell for periodic cleanup operation. All crud collected from the Cutting Station and Clamping Table is drawn into a centrifugal separator and dropped into a water-filled filter. The air stream is then discharged back into the cell. The filter in the water-filled container must be replaced periodically. All Crud Collection System components were not installed or tested when the decision was made to refocus the test program. The plans to test the Portable Vacuum System were also canceled in the refocused test program.

All changeout operations are performed in the manual mode. The RM-10A attached to the RBT is required to change out the filters. During waste removal operations, a waste transfer drum with a new basket filter is loaded into the cell. Once in position, the RBT is positioned over the drum and the auxiliary hoist is grappled to the drum. Once grappled, the drum is moved next to the collection container and the drum lid and filter removed. Using the RM-10A manipulator, the auxiliary crane is hooked to the crud collection container lid and the mechanical latch unlocked. The lid is lifted by the auxiliary hoist to provide clearance for the RM-10A

manipulator. Once the lid is cleared, the filter basket is lifted from the container and placed in the drum. The new filter is then placed into the crud collection container and the lid repositioned and latched in place. After the crud collection container is secured, the lid is replaced on the drum. This drum is then positioned for removal by a crane. No remote changeout operations were included in the refocused test program; therefore, the capability of the system design to permit remote changeout of filters was not demonstrated.

2.2.3.3 Cutting Fines

As a result of end fitting removal operations, zirconium, Inconel, and stainless steel fines and chips are generated. These fines and chips are washed into a collection system where they are maintained until removed from the cell. This collection system consists of a roughing filter for the collection of springs, rod tips, and large pieces of the fuel assemblies which may become loose during disassembly operations. Downstream of this filter is a bag filter for the collection of the fines and chips.

All waste collection operations are performed in the manual mode. The RM-10A attached to the RBT is required to change out the filters. During waste collection operations, a waste transfer drum with new basket filters and a roughing filter is loaded into the cell. Once loaded, the RBT is positioned over the drum and the auxiliary hoist connected to the drum. Once connected, the drum is moved to the Upper Cutting System and the drum lid and filters removed. Using the RM-10A manipulator and auxiliary hoist, the roughing filter is removed and placed in the drum. The removal operation only requires that the filter be lifted vertically to clear the container. Once removed, the new filter is placed in the collection hopper. Next, using the RM-10A, the auxiliary hoist is attached to the bag filter housing. Once the mechanical latches have been removed by the RM-10A manipulator, the bag filter is lifted from the housing and placed into the drum. The new filter is then lowered into the housing and the lid lowered in place and latched.

For BWR fuel processing, the same operation as defined above for the bag filter is repeated at the Lower Cutting System. Replacement of the roughing filter at the Lower Cutting System is required infrequently since there are no springs to be collected at the lower end. Once filled, the lid is placed on the drum and the drum repositioned for removal from the cell. No remote changeout operations were included in the refocused test program; therefore, the capability of the system design to permit remote changeout of filters was not demonstrated.

2.2.3.4 Cutting Tools

During fuel assembly consolidation processing, the end fittings are cut from the assemblies. The top end fittings are removed from PWR assemblies using the rotary tool module (refer to Drawing 9315-M-1606) equipped with internal diameter (ID) tube cutters and a drill bit. A skirt cutter is required for the B&W assemblies, in addition to the ID tube cutter. The top end fittings are removed from BWR assemblies using the end mill fixture (refer to Drawing 9315-M-1650), and the bottom end fittings are removed using the band saw fixture (refer to Drawing 9315-M-1605).

The cutting tools are replaced by remotely removing the turret module from the Upper Cutting System using the RBT and RM-10A manipulator. The turret module is disconnected from the X-saddle using an impact wrench which is operated by the RM-10A. The RBT auxiliary hoist is then hooked to the turret module by the RM-10A and moved to the lay down area for removal from the cell. Once at the lay down area, the auxiliary crane is disconnected and the ex-cell crane connected so that the turret module may be removed from the cell. The turret module is then moved to the hot shop for decontamination. Once decontaminated, the tools are manually removed and replaced with new ones. The turret module is then moved back into the cell and reinstalled in the reverse order of removal.

No remote changeout operations were included in the refocused test program; therefore, the capability of the system design to permit remote changeout of the cutting tools was not demonstrated.

2.2.4 Off-Normal Events

The system has been reviewed to establish a list of credible off-normal events, addressing potential accident conditions which can occur during normal system operation. This list covers potential events dealing with the irradiated conditions of the fuel being consolidated, and the methods used for handling, disassembly, and consolidation of the fuel. Based on this list, features have been incorporated into the design to minimize the potential of occurrence as well as the recovery from these events. The items on this list are:

- o Stuck/released fuel rod
- o Broken fuel rod (broken prior to loading into the cell or broken during the process)
- o Fuel rod which cannot be gripped for rod extractions (e.g., swelled)

- o Fuel assembly/rod that cannot be consolidated
- o Fuel rod stuck in end fitting during end fitting removal at the cutting system
- o ID tube cutter stuck in guide tube
- o Broken saw blade, drill bit or end mill stuck in assembly
- o Gripper stuck shut with fuel rod gripped
- o Rod bundle jammed in funnel during canister loading
- o Assembly that cannot be consolidated

In addition to the off-normal events, the system has been designed and the consequences analyzed for the off-normal events presented in the Design Bases Accident Report. Equipment failure is not considered an off-normal event. The system is designed with features to protect the system if a failure should occur (e.g., system locks in place) and is designed for recovery operations. Therefore, only those situations dealing with fuel assembly processing are addressed in these section.

2.2.4.1 Design Features to Mitigate Off-Normal Events

Features have been incorporated into the design to detect potential fuel problems and to minimize the potential of damaging the fuel. For all fuel transfer operations and consolidation operations, the system equipment has been designed to accommodate fuel assemblies with a permanent bow of 1.5 inches or less and fuel rods with a permanent set bow of 1.5 inches or less. Based on an evaluation of the fuel condition, no fuel shipped on site should exceed this condition.

In addition, hold points have been provided during the automatic processing of the fuel to detect and avoid fuel damage. These hold points are provided at critical steps in the process to enable detection of problems. A hold point is provided at the Cutting System to verify alignment prior to cutting operations. A hold point is provided after initial rod extraction operations to detect rods which were broken prior to cell loading. A hold point is also provided after the rods have been pulled and released to determine if all rods are completely withdrawn from the assembly and to determine if all rods are released from the gripper. This hold point is provided to avoid damaging rods during side transfer operations.

In addition to the hold points, the system has been designed to

prevent damaging of the fuel. The rod grippers automatically release between 150 and 200 pounds pulling force on the rods. This load is well below the yield point of the rods. A sensor has been provided in the consolidation hopper to measure the rod bundle heights. The sensor will shut down the system if the height of the bundle exceeds the canister opening, avoiding jamming of the rods into the canister. Equipment and special end effectors have been provided for the recovery of dropped fuel and fuel pellets, and the system has been provided with the capability of loading an intact assembly into a canister.

In addition to the design features for off-normal fuel conditions, the system has been designed to minimize fuel and equipment damage. All fuel transfer operations require two different actions to take place before an assembly is released. This avoids dropping of an assembly or fuel canister. All clamps are self-locking to avoid release of an assembly by an external force (e.g., seismic event or collision), and electrical and hard stops have been provided to protect the equipment and the fuel.

2.2.4.2 Recovery Procedures

This section identifies the steps necessary to recover from the off-normal events identified in 2.4 above. All recovery operations will be performed in the manual operating mode, using the RM-10A manipulator in conjunction with the RBT or Manipulator Transporter System (depending on the off-normal event). Two operators are required for all recovery operations. One operator will control either the RBT and the CCTV System from the Operator Control Station. The second operator will control the Manipulator Transport System, RM-10A manipulator, and its CCTV System from the Maintenance Control Station. All operations will be performed in place, temporarily shutting the system down, or the problem assembly will be moved to the Off-Normal Station and recovery procedures performed as normal fuel processing continues. Equipment (e.g., portable camera, rake, vacuum system, etc.) has been provided for the location and recovery of equipment, components, and fuel which may be dropped during operations. No testing of the ability of the designed system to recover from off-normal events as described in the following paragraphs was included in the refocused test program.

2.2.5 System Completion For Refocused Testing

When the decision was made to refocus the Phase III test program, the priority of fabrication, assembly, and installation activities was re-evaluated. Only those activities necessary to support the Integrated Systems Testing of the W 17x17 fuel assemblies were scheduled for completion. Furthermore, the decision by DOE to not

perform Phase IV testing also altered the requirements for completing certain activities related to system completion. Table 2.2-1 presents a summary of the completion status of various components of the Rod Consolidation System.

TABLE 2.2-1

FABRICATION/ASSEMBLY/INSTALLATION COMPLETION STATUS

S N.	SYSTEM TITLE	PHASE III BASELINE DESIGN STATUS			COMMENTS
		FAB	ASSM	INSTALL	
11	Control Hardware/Software	100	100	100	
12	CCTV System	100	100	100	
13	RM-10A	100	100	100	
14	RBT	100	100	100	See general notes.
15	MT	100	100	100	See general notes.
25	Cables	100	100	99.5	Cables for Crud Collection System not installed.
11	Fuel Assembly Storage Rack	100	100	100	A nonconformance in rack spacing was accepted for Cold Testing.
12	Downender	100	100	100	See general notes.
13	Staging and Cutting System	100	100	100	See general notes.
14	Upper Cutting System	100	100	100	See general notes.
	* PWR Clamp Assembly	100	100	100	See general notes.
	* BWR Clamp Assembly	100	95	N/A	BWR clamp assembly fully fabricated and 95% assembled.
15	Lower Cutting System	100	100	100	Design change for remote maintenance has been completed but will not be implemented.
16	Chip Collection System	85	85	85	Collection hopper and piping for lower cutting system not installed.
17	Crud Collection System	90	90	90	Ductwork not installed. Cable procured but not being installed.
18	Fuel Assembly Handl. Fixture				
	* PWR fuel types	100	100	100	Only one Fuel Assembly Handling Fixture is installed at a time in the Storage Rack.
	* BWR fuel types	100	100	100	

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TABLE 2.2-1 (continued)

FABRICATION/ASSEMBLY/INSTALLATION COMPLETION STATUS

IS D.	SYSTEM TITLE	PHASE III BASELINE DESIGN FAB	STATUS ASSM	INSTALL	COMMENTS
421	Clamping Table	100	100	100	See general notes.
	* PWR Clamp Assembly	100	100	100	See general notes.
	* BWR Clamp Assembly	100	99	N/A	Load cells are not mounted in fuel support saddle.
422	Rod Extraction System	100	100	100	See general notes.
	* 17X17 Pull Heads	100	100	100	See general notes.
	* 15X15 Pull Heads	100	75	N/A	Out of scope design improvements for force measurements are not implemented.
	* 8X8 Pull Heads	100	75	N/A	Out of scope design improvements for force measurements are not implemented.
423	Side Transfer/Compact. System	100	100	100	See general notes.
424	Rod Loading	100	100	100	See general notes.
425	Rod Consolidation Table	100	100	100	See general notes.
431	Fuel Canister Upender	100	100	100	See general notes.
433	Fuel Canister Storage Rack	100	100	100	See general notes.
434	Fuel Canister Grapple	100	100	100	See general notes.
441	NFBC Loader	100	100	100	See general notes.
442	NFBC Upender	100	100	100	Motor removed for use on Rod Loading System hopper elevation drive.
44	NFBC Container Storage Rack	100	100	100	See general notes.
451	Waste Container Transf. Fixt.	100	100	100	See general notes.
452	Off-Normal Table	100	100	100	See general notes.
453	Equipment Storage Racks				
	* RM-10A tools & cell equ.	100	100	100	See general notes.
	* FAHF	100	100	100	See general notes.
	* RM-10A Manipulator	100	0	0	See general notes.
	* Load Cell Removal tool	100	100	100	See general notes.
455	RM-10A End Effectors & Maint. Tools	90	90	N/A	Pull head removal tool not done. Interface

TABLE 2.2-1 (continued)

FABRICATION/ASSEMBLY/INSTALLATION COMPLETION STATUS						
S N.	SYSTEM TITLE	PHASE III BASELINE DESIGN STATUS		INSTALL		COMMENTS
		FAB	ASSM			
						adapter for RM-10A is not installed.
one	Broken fuel rod container	0	0	0		Design completed.
one	End fitting waste containers	0	0	0		Design completed.
one	Equipment Maint. Container	0	0	0		Design completed.
16	Spare parts	100	N/A	N/A		All spares for cold testing are available.

GENERAL NOTES:

- The following general notes apply to all incell equipment:
- 1. Equipment has not been painted.
 - 2. Permanent cable clamps have not been installed.
 - 3. Some lifting lugs have not been installed.

RL - Repair Log NCR - Nonconformance Report

3.0 TEST PROGRAM DESCRIPTION

The Phase III Test Program as it was initially developed and described in the Phase III Test Plan (Reference 3.4.1) provided for functional testing of all components and systems comprising the Rod Consolidation System. This functional test was to be performed in increasing sophistication from individual component testing, to subsystem testing, to full system testing, with final integrated testing of the Rod Consolidation System and all supporting systems using mock-up fuel assemblies, square and round consolidated fuel storage canisters, and NFBC containers provided by DOE. Three types of tests comprised the test program in order to accomplish the functional testing objective. These tests are described in the following sections.

3.1 COMPONENT CHECKOUT TESTS (FACTORY ACCEPTANCE TESTS)

Component Checkout Tests check out purchased or fabricated components and engineered systems that will be assembled to perform a specific part of the Rod Consolidation System. The purpose of these tests is to verify the fit and function of each fabricated part to performance requirements. Payment of various vendors and subcontractors for delivered components and equipment was linked to satisfactory completion of the Factory Acceptance Tests (FATs). The following paragraphs describe the various types of component checkout tests that were performed.

3.1.1 Engineered Systems

The Component Checkout Test for the following purchased engineered systems took place at the individual vendors' facilities:

- o Control Panels and Operator Consoles
- o Closed Circuit Television Surveillance System
- o RM-10A Manipulator
- o Robotic Bridge Transporter
- o Manipulator Transporter
- o Lower Cutting System (Band Saw)

The test for the Control System Software was performed at the Cold Test Facility.

The engineered systems subcontractors were required to prepare the formal test procedures for the performance tests. These were identified as FAT procedures which were approved by HALLIBURTON NUS. The purpose of the FATs was to demonstrate that the requirements as specified in the technical specifications for the specific system were met. All FATs performed on engineered systems were monitored by HALLIBURTON NUS personnel. Copies of completed FAT procedures that were used to perform the FATs are part of the QA/QC records that will be turned over to DOE at the end of the Phase III effort. The technical specifications that define the requirements for the individual engineered systems are also part of the QA/QC records that are turned over at the end of the Phase III effort.

Table 3.1-1 provides a listing of the engineered systems and their corresponding technical specifications and FAT documents.

3.1.2 Fabricated Systems

The Component Checkout Test for the systems fabricated by the system fabricator were also designated as FATs. These tests were performed at the HALLIBURTON NUS Cold Test Facility in Pittsburgh, Pennsylvania. HALLIBURTON NUS prepared Test Acceptance Criteria for each test objective and then developed detailed step-by-step test procedures to accomplish the test objectives.

The tests performed on the equipment made by the system fabricator were of four basic types:

Operating Tests	-	Check that all moving part operated satisfactorily.
Load Tests	-	Check that designed loads could be accommodated without damage to the equipment.
Dimensional	-	Check specific structural dimensions
Component	-	Check that the assembled Removal Tests components had sufficient accessibility for remote removal

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TABLE 3.1-1

ENGINEERED SYSTEMS FACTORY ACCEPTANCE TESTS

SYSTEM/COMPONENT	PROJECT SPECIFICATION WHICH IDENTIFIES REQUIREMENTS	PREPARE SPECIAL TEST ACCEPTANCE CRITERIA/PROCEDURE (NUS OR VENDOR)	CERTIFICATE OF COMPLIANCE	COMMENTS
1.0 ENGINEERED SYSTEMS				
1.1 Process Control Panels Hardware Software	9315-E-600 9315-E-601	VENDOR/VENDOR VENDOR/VENDOR	Received	Test Acceptance Criteria incorporated into Test Procedure and not issued as a separate document. NUS approved
1.2 Closed Circuit Television	Part of Request for Proposal No. 015	VENDOR/VENDOR VENDOR/VENDOR	Received	Same as comment for 1.1
1.3 RM-10A	9315-M-205	VENDOR/VENDOR	Received	Same as comment for 1.1
1.4 Robotic Bridge Transporter	9315-M-201	VENDOR/VENDOR	Received	Same as comment for 1.1
1.5 Manipulator Transporter	9315-M-202	VENDOR/VENDOR	Received	Same as comment for 1.1
1.6 Band Saw	9315-M-211	NUS/NUS	Received	Same as comment for 1.1 Testing was done in two phases. Preliminary test at vendor factory and final test at the NUS Cold Test Facility.

Table 3.1-2 provides a listing of the subassemblies, assemblies, and systems that were tested. The listing identifies the percent completion for each FAT at the completion of Phase III activities, due to the refocusing of the test program.

Copies of the Test Acceptance Criteria (TAC) documents and the completed FAT procedures are included with the QA/QC documents that are submitted to DOE at the completion of the Phase III effort.

The numbering of TAC documents and the Test Procedure (TP) documents is as follows:

All TACs are numbered 9315-TAC-230-(plus the WBS no.).

All TPs are numbered 9315-TP-230-(plus the WBS no.).

All FATs performed on equipment that was installed in the Test Cell were performed under the direction of a certified HALLIBURTON NUS test engineer following the step-by-step procedures that had been approved by HALLIBURTON NUS project management. The test results of all FATs were reviewed by the Project Quality Assurance Engineer and the Project Engineer before the tests were accepted as complete.

The first FAT on equipment installed in the Test Cell was initiated on July 18, 1991, and the last FAT was completed on May 20, 1992.

3.1.3 Commercially Procured Components

HALLIBURTON NUS ordered commercially available components based on selecting specific catalogue items that met the HALLIBURTON NUS design requirements. With only a few exceptions, HALLIBURTON NUS did not require any special testing by the vendors and accepted the vendors standard factory testing program as adequate to ensure that HALLIBURTON NUS was obtaining the component that will perform as promised in the vendors' catalogues.

Table 3.1-3 describes the specific testing that was conducted on the more significant commercially procured items.

Copies of vendor test data and certificates of compliance that were provided to HALLIBURTON NUS are included in the QA/QC documentation that is submitted to DOE at the end of the Phase III effort.

TABLE 3.1-2

JS OF FACTORY ACCEPTANCE TESTS PERFORMED ON EQUIPMENT ASSEMBLED BY THE
FABRICATOR

#	TEST TITLE	COMPLETION % COMPLETE		STATUS		% COMPLETE FOR REFOCUSED TEST PROGRAM
		OT	LT	DC	CRT	
	Fuel Assembly Storage Rack	100	100	100	100	100
	Downender	100	100	NR	0	100
	Staging and Cutting	100	100	NR	0	100
	Upper Cutting System	100	NR	NR	0	100
	Lower Cutting System	100	NR	NR	0	NR
	Chip Collection System	100	NR	NR	0	100
	Crud Collection System	100	NR	NR	0	NR
	Fuel Assembly Handl. Fixture	100	100	NR	NR	100
	Fuel Assembly Clamping Table	100	NR	NR	0	100
	Rod Extraction	100	NR	NR	0	100
	Rod Compaction	100	NR	NR	0	100
	Rod Loading	100	NR	NR	0	100
	Rod Consolidation Table	NR	NR	100	NR	100
	Fuel Canister Upender	100	NR	NR	0	100
	Fuel Canister Storage Rack	100	100	100	100	100
	Fuel Canister Grapple	100	100	NR	NR	100
	NFBC Loader	100	NR	NR	0	100
	NFBC Upender					NR
	NFBC Storage Rack	100	100	100	100	100
	Waste Handling Trans. Fixture	100	100	NR	0	NR
	Off-Normal Station	100	100	NR	0	NR
	Equipment Storage Rack	NR	NR	100	NR	NR
	RM-10A End Effectors	25	25	NR	NR	NR

Operating Test

Load Test

Dimensional Check

Component Removal Test

Not Required

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COMMERICALLY PURCHASED COMPONENTS FACTORY ACCEPTANCE TESTS

SYSTEM/COMPONENT	PROJECT SPECIFICATION WHICH IDENTIFIES REQUIREMENTS	PREPARE SPECIAL TEST ACCEPTANCE CRITERIA/PROCEDURE (NUS OR VENDOR)	CERTIFICATE OF COMPLIANCE	COMMENTS
1.5 Resistance	9315-E-604	Not Required	Received	Vendor-supplied test procedure and calibration test data.
1.6 Incell Cables	9315-E-606	Not Required	Received	Vendor-performed standard factory tests.
1.7 Test Cell Lights	9315-E-612	Not Required	Received	Test performed when SOTs were performed.
1.8 Acoustical	9315-E-615	Not Required	Received	This is an off-the-shelf item. Proper performance was determined in the Cold Test Cell when all equipment was installed and microphones could be properly positioned.
1.9 Uninterrupted Power Supply	9315-E-608	Not Required	Received	Test Acceptance Criteria incorporated into Test procedure which was submitted to NUS for this off-the-shelf item. A special battery rundown test procedure was also prepared and submitted for information.

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COMMERCIALY PURCHASED COMPONENTS FACTORY ACCEPTANCE TESTS (continued)

SYSTEM/COMPONENT	PROJECT SPECIFICATION WHICH IDENTIFIES REQUIREMENTS	PREPARE SPECIAL TEST ACCEPTANCE CRITERIA/PROCEDURE (NUS OR VENDOR)	CERTIFICATE OF COMPLIANCE	COMMENTS
1.10 Proximity Sensors	9315-E-610	Not Required	Received	Proper performance was checked after input up to Process Control System during Systems Operations Tests.
1.11 Load Cell	9315-E-614	Not Required	Received	Same as 1.10.
1.12 Noble Gas	Catalogue Item	Not Required	Received	Same as 1.10
1.13 Smoke Detectors	9315-E-613	Not Required	Received	
1.14 Level Switches	Catalogue Item	Not Required	Not Requested	Same as 1.10.
1.15 Flow Sensor	Catalogue Item	Not Required	Not Requested	Same as 1.10.
1.16 Seismic Switch	Catalogue Item	Not Required	Not Requested	Performance tested when installed in Control Room and connected to the Process Control System.
1.17 Connectors	9315-E-616	Not Required	Received	Same as 1.10.
1.18 Miscellaneous	Catalogue Item	Not Required	Not Requested	Performance tested when systems were energized for SOTs.

3.2 SYSTEM OPERATIONS TESTS

3.2.1 Test Objectives

The primary objective of the System Operations Tests (SOTs) was the following:

- o Verification that all sensors have been properly calibrated and initially set for proper operation and protection of the mechanical systems.
- o Verification of system mechanical operation under loaded and unloaded conditions.
- o Verification of process system part programs with the equipment under loaded and unloaded conditions.
- o Verification of system interfaces.
- o Verification of Process Control System software interlocks.
- o Verification of motor fault response
- o Verification of the performance of specific system processing features such as end fitting removal or rod pulling, transferring, compacting, and loading.

3.2.2 Test Documents

TAC and detailed step-by-step TPs were developed for each of the 22 systems or subsystems that were tested. The TAC and TP documents were reviewed by DOE who had approval authority on the TAC documents. Incorporation of DOE comments on the TP documents was based on mutual agreement as to the merits of such comments in achieving the test objectives.

Table 3.2-1 is an example of the table of contents that was utilized in the development of the individual TPs.

TABLE 3.2-1

EXAMPLE OF THE TABLE OF CONTENTS FOR THE SYSTEM OPERATIONAL
TEST PROCEDURES

<u>Section</u>	<u>Title</u>
1.0	OBJECTIVE OF TEST
2.0	PREREQUISITES
3.0	INITIAL TEST CONDITION
4.0	ENVIRONMENTAL CONDITIONS
5.0	SPECIAL PRECAUTIONS
6.0	SPECIAL EQUIPMENT REQUIRED
7.0	TEST DATA RECORDING
8.0	DETAILED TEST STEPS
9.0	POST-PERFORMANCE REVIEW AND APPROVAL
10.0	RETENTION OF TEST RECORDS
11.0	REFERENCES
APPENDIX A	EQUIPMENT SETUP
APPENDIX B	SAFETY PROCEDURES
APPENDIX C	PHOTO DOCUMENTATION REQUIREMENTS
APPENDIX D	TEMPORARY PROCEDURE CHANGE NOTICE AND REPAIR LOG
APPENDIX E	CCTV ASSESSMENT FORM
APPENDIX F	TRAINING SIGN-OFF SHEET

3.2.3 Test Administration

Control of testing activities was maintained through adherence by the assigned test conductors to the requirements of the Test Administration Manual (Reference 3.4.2). This manual provided detailed guidelines to be followed by the test conductors so that the validity of the testing and the integrity of the test data could be maintained. A copy of the manual will be included with the QA/QC records to be submitted to DOE at the completion of the Phase III effort.

3.2.4 Informal Operational Readiness Reviews

The completion of the prerequisite section of each SOT constituted the performance of an informal Operational Readiness Review (ORR). The purpose of the informal ORR was to ensure that the procedures, equipment, and personnel were adequately prepared for the test so that the test would provide valid test data and that it would be conducted in a safe manner so as not to endanger personnel and equipment.

3.2.5 Tests Performed

The original test program as initially planned for the SOTs in the Phase III Test Plan was reduced when the decision was made in the Spring of 1992 to refocus the testing activities. Table 3.2-2 lists all the SOTs that were contemplated to be performed, the specific test sections that were required to be completed for the refocused test program, and the actual completion status of those tests. The results of the SOTs performed are discussed in Section 4.0 of this report.

The performance of the first SOT was initiated on November 9, 1991, and the last SOT was completed on October 19, 1992. The test results and analysis of the completed tests are provided in Appendices I-4.1 through I-4.21.

3.3 INTEGRATED SYSTEMS TESTS

3.3.1 Test Objectives

The objective of the Integrated Systems Tests (ISTs) is to demonstrate the ability of the installed Rod Consolidation System to operate in the automatic mode to consolidate rods and to operate

TABLE 3.2-2

SYSTEMS OPERATIONS TEST COMPLETION STATUS

TEST NO. COMPONENT SOT-Tp-	TEST TITLE	SECTION REQUIRED FOR REFOCUSED TEST PROGRAM	SECTIONS
201	Rod Extraction	8.1	8.1
202	Clamping Table	8.1.3,8.1.4,8.1.6,8.3	8.1.3,6.1.4,6.1.6,8.3
203	Downender	8.5	All of Section 8.
204	NFBC Upender	None	All of Section 8 except 8.9.
205	Fuel Assembly Handling Fixture	8.5	8.5
206	Fuel Canister Upender, Grapple, and Closure	All of Section 8	All of Section 8
207	Rod Compaction/ Loading	8.4,8.5.9-11.13 and 15	8.4,8.5.9 - 11, 13 and 15
208 A/B	Chip/Crud Collection	None	None
208 C	Waste Handling Transfer Fixture	None	None
209 A	Staging & Cutting	8.4	8.4
209 B	Upper Cutting System (All Fuel Types)	None-See Test 209 D.	None - See test 209 D
209 C	Lower Cutting System	None	8.1.1 to 8.1.6
209 D	Upper Cutting System (W - 17x17)	8.3	8.3
211	NFBC Loader	8.4	8.4
212	Robotic Bridge	None	None
213	Transporter	8.1.8.2,8.3 except 8.3.1.	8.1,8.2
214	RN-10A End Effectors Manipulator	8.3.2. and 8.3.3	None
501	Fuel Assembly Storage Rack	None	All Section 8. Some retests not performed.
503	Off-Normal Station	All of section 8 (will only use Load Cells in shelves 2A and 2C)	All of Section 8 (Some problems with load cells in shelf 6 and 7B)
		None	8.1.1-8.1.3.8,3.3,8.3.4,8.6.1

TABLE 3.2-2

SYSTEMS OPERATIONS TEST COMPLETION STATUS

TEST NO. COMPONENT SOT-TP-	TEST TITLE	SECTION REQUIRED FOR REFOCUSED TEST PROGRAM	SECTIONS
504	NFBC Container	None	All of Section 8
505	Storage Rack Fuel Canister	8.1 to 5	8.1 to 5
600	Storage Rack CCTV/Audio	Not Required	8.1 to 8.6 (Some retests not performed)
601	Surveillance System Control System	8.1 - 8.9, 8.10 (Perform only on devices to be used in refocused	8.1 to 8.9, except 8.9,5 and 6 8.10 (Section required for IST).

in the semi-automatic mode to recover from off-normal events, and to perform maintenance tasks. To accomplish these objectives, the following three separate ISTs were planned to be performed when the Phase III Test Plan was developed:

Normal Operational Testing

This test was selected to demonstrate the ability of the installed system to process four fuel types while operating in the automatic mode.

Off-Normal Operational Testing

This test was selected to demonstrate the ability of the installed system to recover from off-normal events while operating in the semi-automatic mode. This test requires the use of the special design features that permit the operators in the Control Room to diagnose the off-normal event and perform the in-cell recovery actions.

Maintenance Operations

This test was selected to demonstrate the ability of the system design to permit the operators in the Control Room to perform in-cell maintenance operations.

3.3.2 Test Documents

The test document process for the ISTs was identical to that described for the SOTs.

Test acceptance criteria were developed for each of the three ISTs which were reviewed and commented on by DOE. A detailed step-by-step TP was also developed for the Normal Operational Testing of the system and was in the revision stage to incorporate DOE comments when the decision was made to refocus the test program to limit the IST to perform normal processing on only the two W 17x17 mock-up fuel assemblies. New TAC and TP documents were developed to cover the refocused testing. A draft TP for the Maintenance Operations IST had also been prepared at this point in time.

Copies of the IST TAC and TP documents and associated DOE comment letters which were no longer applicable when the test program was refocused will be included with the QA/QC records that will be sent to DOE at the completion of the Phase III effort.

3.3.3 Test Administration

Control of testing activities for IST was identical to the controls utilized for the SOTs.

3.3.4 Operational Readiness Review

A formal ORR was conducted following the guidelines specified in the ORR Plan (Reference 3.4.3). The original signature copy of the ORR Plan is included with the QA/QC Records that will be sent to DOE at the completion of the Phase III effort.

An operational readiness assessment was made by a committee composed of HALLIBURTON NUS employees and a representative of DOE. The initial kickoff meeting of the ORR Committee was held at the Cold Test Facility on August 6, 1992 and the final meeting was held on October 29, 1992 when the assessment made by the committee was presented to the HALLIBURTON NUS Project Manager. The assessment verified the following:

- o That the operational readiness of the facility structures, hardware, and systems is adequate based on an assessment of (1) as-built conformance with the design requirements; and (2) Factory Acceptance Tests (FAT) and modified System Operational Test (SOT) results.
- o That the controlling documentation is adequate based on an assessment of (1) safety documents; (2) quality records; (3) key drawings; (4) operating manuals and procedures; (5) deficiency/nonconformance documentation; (6) audit and appraisal reports; and (7) facility certification reports.

At the conclusion of the review, two findings were identified by the ORR Committee that required closure by the Project Team in order to initiate the Integrated Systems Testing. The deficiencies were corrected by the Project Team and the two findings were closed out by the ORR Committee on November 10, 1992.

The final report prepared by the ORR Committee (Reference 3.4.4) was transmitted to DOE by Reference 3.4.5.

3.3.5 Testing Performed

Integrated Systems Testing in accordance with Test Procedure 9315-IST-215A, Revision 2, was initiated on November 11, 1992 and was completed on November 19, 1992. The test results and analysis of the completed test are discussed in Appendix I-4.22 of this document.

3.4 REFERENCES

- 3.4.1 Project Specification 9315-P-109 Revision 5
Prototypical Spent Fuel Rod Consolidation System
Test Plan.
- 3.4.2 Project Specification 9315-P-120 Revision 1 Test
Administration Manual for System Operations Tests
and Integrated Systems Tests.
- 3.4.3 Project Specification 9315-P-117 Revision 4
Operational Readiness Review Plan for Prototypical
Spent Fuel Rod Consolidation Equipment.
- 3.4.4 DOE Fuel Rod Consolidation Project Operational
Readiness Review Final Report dated November 25,
1992.
- 3.4.5 HALLIBURTON NUS Environmental Corporation letter
no. ED-DOE-PVJ-92-2501 dated November 30, 1992.

4.0 SUMMARY OF TESTS AND TEST RESULTS

Phase III activities required that the Prototypical Rod Consolidations System be tested for compliance with both the functional and contractual requirements. As a result, a comprehensive test program (refer to Section 3.0 of this volume) was defined. This program required testing of the system in several stages throughout the development process. These stages consisted of testing the system in increasing complexity from individual component testing to full system testing. This testing was divided into three main categories as follows:

- o Factory Acceptance Tests (FATs)
- o System Operational Tests (SOTs)
- o Integrated System Tests (ISTs)

This section provides a summary review of these tests and the results obtained during testing.

4.1 FACTORY ACCEPTANCE TESTS (FATs)

4.1.1 Summary of Tests

The FATs were developed to check out all purchased and fabricated assemblies. This testing consisted of verifying the fit and function of these assemblies prior to being released for installation into the Cold Test Facility. Each test was performed by the vendor under contract to provide the equipment prior to being either shipped or released for final installation. Each test was performed to approved procedures which identified both the step-by-step instructions and the criteria by which the results were to be judged acceptable.

The FATs were divided into four basic tests. Each of these tests was performed, as appropriate, on all Prototypical Rod Consolidations System assemblies. These tests consisted of the following:

- o Dimensional checks: All purchased components, purchased engineered system, and fabricated assemblies were dimensionally checked for compliance to the fabrication drawings or vendor drawings. These dimensional checks were conducted for all piece parts, subassemblies, and assemblies.

- o Operating Tests: All purchased components, purchased engineered systems, and fabricated assemblies were checked for proper operation. All moving components and piece parts were inspected for free and unrestricted movement (such as motors, bearings, gear boxes, etc.) per vendor catalog data. In addition, all fabricated assemblies were checked for free unrestricted movement over their designed range of travel as specified on either the vendor drawings, design specifications, or fabrication drawings.
- o Load Tests: All purchased engineered systems and fabricated assemblies were tested, as appropriate, under design loads. This testing checked each assembly for free unrestricted movement over their design range of travel under 125% to 150% of their design loads. This testing was applied to only those assemblies which translated or transferred fuel from one position to another.
- o Component Removal Tests: All purchased engineered systems and fabricated systems were to be tested for maintenance. This test specified the removal and reassembly of all assemblies which would need to be removed over a 30-year life for servicing. However, due to the refocusing of the test program, this test sequence was eliminated from the program.

4.1.2 Summary of Test Results

All of the purchased components, purchased engineered systems, and fabricated assemblies were judged acceptable for final installation as a result of these tests. All were found to be within tolerance for proper setup and functioned under both unloaded and loaded conditions, as appropriate, over their design range of travel. All inspection reports, completed procedures, and certificates of compliance are provided as part of the QA/QC data packages. Each is filed by system and is provided as part of the Phase III deliverables.

4.2 SYSTEM OPERATIONAL TEST (SOT)

4.2.1 Summary of Tests

The SOTs were developed to check out all of the assembled Prototypical Rod Consolidation System equipment. This testing consisted of verifying the proper operation of the equipment and the proper interfacing of the equipment to the Control System prior to being released for Integrated System Testing (IST). Each test was performed by a qualified test conductor to approved procedures. These procedures identified both the step-by-step instructions and the criteria by which the results were judged acceptable.

The SOTs were divided into nine basic tests. Each of these tests was performed as appropriate on all the Prototypical Rod Consolidation System equipment. Initially, these tests were defined for each of the five fuel types (W 17x17, W 15x15, B&W 15x15, CE 14x14, & GE 8x8) identified for Phase III testing. However, as a result of the refocussing of the test program, all fuel types except the W 17x17, and the equipment required for normal fuel processing of the W 17x17, was eliminated from the test program.

4.2.2 SOT Procedure Format

Each SOT procedure was formatted identically, as appropriate, and contained the required information for the test conductor to successfully perform the test. An outline of a typical SOT procedure and the purpose of each section are provided below.

SECT.	TITLE	PURPOSE
1.0	Objective Of Test	States test objectives for each specific test procedure.
2.0	Prerequisites	Provides a list and sign-off of various tasks and documents which must be completed prior to initiating the test.
3.0	Initial Test Conditions	Provides a list and sign-off of the required initial configuration of the test equipment and support equipment prior to the test.

SECT.	TITLE	PURPOSE
4.0	Environmental Conditions	Lists the environmental conditions required for the test and a sign-off to verify that the conditions were met.
5.0	Special Precautions	Lists any specific safety considerations to be observed during the test.
6.0	Special Equipment Required	Provides a list of test equipment and materials needed to perform the test.
7.0	Test Data Recording	Provides administrative instructions pertaining to the procedure.
8.0	Detailed Test Steps	This section contains the detailed test steps required to perform the test and provides a sign-off to verify that the test was or was not successfully completed.
9.0	Post Performance Review And Approval	Provides a sign-off for the test committee to verify that the completed test has been reviewed and accepted.
10.0	Retention Of Test Results	This section provides instruction on what to do with the completed test procedure.
11.0	References	Lists documents needed to reference the basis for the Test Acceptance Criteria.
App.A	Equipment Set-up	Contains instructions for setup of the drives, resolvers, and sensors to enable the equipment to operate safely within its operating parameters.
App.B	Safety Procedures	Provides a list of safety instructions to follow while the test is being performed.

SECT.	TITLE	PURPOSE
App.C	Photo Documentation Requirements	This appendix provides a list of certain equipment operations which must be photographically documented and contains the photo log which lists the specific photographs taken during the test.
App.D	Temporary Procedure Change Notice (TPCN) and Repair Logs (RL)	This appendix contains TPCNs or RLs filled out during the test to document changes, problems, or exceptions taken to the procedure.
App.E	CCTV Assessment Form	Provides a form to document the view provided by the CCTV System during certain operations.
App.F	Training Sign-off Sheet	Provides a sign-off to verify that the personnel involved with the test have been trained by the test conductor to administer the test.

All test data and completed forms (TPCNs, RLs, ect.) are provided in the appropriate section of the completed test procedures which are included as appendices I-4.1 through I-4.22 of this volume.

4.2.3 Summary of Tests Results

All of the Prototypical Rod Consolidation System Equipment was judged acceptable for Integrated System Tests. Each was found to meet the required parameters for handling, transporting and positioning either a fuel assembly, fuel rods, or canister for normal process operations for the W 17x17 fuel type. The specific results and completed test procedures are provided as Appendices I-4.1 through I-4.22 of this volume.

4.3 INTEGRATED SYSTEM TEST (IST)

4.3.1 Summary of Tests

The ISTs were developed to check out the complete Prototypical Rod Consolidation System. This testing consisted of verifying the

proper processing of the W 17x17 fuel types and sequencing of all equipment for normal operations prior to being released for shipping.

This test was performed by a qualified test conductor according to approved procedures. These procedures identified the step-by-step instructions and criteria by which the results were to be judged acceptable.

The ISTs were initially set up to test all operating conditions. The normal process IST was set up to test four (W 17x17, W 15x15, B&W 15x15, & GE 8x8) fuel types. In addition, the IST was to test all off-normal conditions and maintenance tasks on a system level. However, as a result of the refocused test program, all testing except normal process operations for the W 17x17 fuel type was eliminated from the test program.

4.3.2 IST Procedure Format

The format of the IST procedure was identical to that of the SOT. For an outline of the IST procedure, refer to Section 4.2.2 above.

4.3.3 Summary of Test Results

The Prototypical Rod Consolidation System was judged acceptable for consolidating W 17x17 fuel types. The system performed as designed with some minor problems. Each of these problems can be easily corrected so that it can be released for Hot Demonstration Testing. However, since this phase of the program has been canceled, all activities beyond completion of this test have been suspended. The specific results and completed test procedure are provided as Appendices I-4.23 through I-4.25 of this volume.

5.0 PROBLEM EVALUATION

This section provides a summary overview of the problems encountered during the preparation of each system for Cold Check-out Testing. It identifies the problems encountered, the fixes made, and the activity being performed when the problems were encountered. This information is presented in tabular form (Ref. Table 5.0) for ease of assimilating all of the data.

The information presented in this table is provided for all of the system equipment. The first column identifies the equipment by name and the work breakdown structure number assigned during this phase of the project. The second column identifies the problems encountered during preparation and testing of the equipment. This section addresses only those problems considered significant. Significant problems are defined as those which required a design change or modification to the existing design. The solutions to these problems are defined in the third column. These solutions are provided in a one-to-one correlation with the problem identified in the first column and define the specific fix or fixes implemented to correct the problem. The last column identifies the activity that was being performed when the problem was encountered. These activities are as follows:

- o FAT - Factory Acceptance Test
- o PTC - Pre-Test Checkout
- o ESA - Equipment Setup Activities
- o SOT - System Operational Test

Again the activities are provided in a one-to-one correlation with the problems identified in the first column.

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Fuel Assembly Storage rack (WBS 1311)	Load cell assembly design did not operate properly to indicate the presence of a fuel assembly.	Floating plate design was replaced with a hinged plate design for more positive contact with the load sensor.	ESA
	The deflection of the fuel assembly was greater than anticipated causing interference with the storage shelf vertical supports.	Spacer plates were added to raise the position of the mockup fuel assembly, within the Fuel Assembly Handling Fixture.	ESA
Downender (WBS 1312)	Movable frame interfered with the main drive system gear reducer when in the full down position.	Notched moveable frame structure around the gear reducer.	PTC
	Movable frame slipped with respect to the stationary base frame when operating the system under loaded conditions.	Recessed moveable frame support bearings into their mounting surface.	FAT
	The 'DOWN' end of travel limit switch for the bottom support operated erratically, causing end-of-travel fault conditions.	Rerouted the end-of-travel sensor cables so they were not in close proximity to the drive motor cables.	SOT
	End-of-travel limit switch for the clamps periodically activated by accident.	Removed slop in the clamp drive train by: o spotting drive shaft to accept set screw. o adding tensioner to preload drive train.	PTC SOT

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Downender (WBS 1312) continued	The fuel assemblies were not properly positioned for end fitting removal operations.	Reprogrammed bottom support to incorporate the corrected positions.	PTC
Staging/Cutting Station (WBS 1313)	The load indicator assembly design transmitted all loads through the load cell sensor diaphragm.	A steel disk was installed on the sensor to protect the diaphragm.	PTC
	The end of the roller screw was damaged when the roller nut reached its end of travel.	Added hard stops to prevent the roller nut from reaching the end of the screw.	PTC
	Cutting station clamps did not close to a position to support BWR fuel types.	Added a steel spacer to the clamps.	ESA
	The assembly grid would catch on the cutting station support grid when being slid horizontally to center it.	Added a solid steel plate cap over all cutting station support grids.	SOT
Upper Cutting System (WBS 1314)	The table interfered with the rod pusher carriage.	Spacer plates were fabricated and installed under the table.	ESA
	Numerous interferences existed between the Upper Cutting System and the Rod Loading System.	All structural interferences were either removed or the Upper Cutting System drives were reprogrammed to eliminate the interferences.	PTC
	The clamp 'Y' axis motor interfered with the Rod Loading System frame.	The motor was repositioned 90 degrees from its original position.	PTC

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Upper Cutting System (WBS 1314) continued	The fuel assembly end fitting configuration was not compatible with the operation of the ID tube cutter.	A striker plate was fabricated and installed on the clamp frame.	PTC
	The end-of-travel hard stop for the 'X2' axis was damaged when engaged.	The motor torque limit was reset so that the motor would stall prior to damaging the hard stop.	SOT
	The Upper Cutting System turret and clamp were improperly positioned in elevation for end fitting removal operations.	A spacer plate was installed under the turret and clamp so that they were properly positioned.	PTC
	The spindle drive cam plate was damaged when the turret was driven to its full up position.	The cam plate was modified to eliminate the interference and a hard stop was installed.	PTC
	There were excessive vibrations in the spindle drive when operating.	A cam follower assembly was fabricated and installed to the top of the spindle drive.	PTC
	The clamp jaws had insufficient travel length to clamp both the top and sides of the assembly.	Longer shoulder screws were installed on the clamp jaws to increase their travel length.	ESA
	There were excessive vibration and noise in the box way slides.	All slides were oiled per the manufacturer's recommendations.	PTC
	No means were provided to remove the turret for cutting tool changeout.	Lifting features were fabricated and installed onto the turret.	PTC

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Upper Cutting System (WBS 1314) continued	The turret locking pin jammed periodicity when being reengaged after the turret was repositioned.	The chamfer on the pin and the size of the hole were increased to provide a greater tolerance.	PTC
	The mounting screws for the spindle drive support bearings failed when the Z-axis was driven to the full down position.	The bearing mounting design was updated consistent with the manufacturer's recommendations and a hard stop was installed.	PTC
	The travel length to engage the spindle drive was too large, causing the assembly to bind.	The turret coupler was repositioned on the gear box drive shaft to decrease the travel length.	PTC
Lower Cutting System (WBS 1315)	The travel length of the end fitting clamp was insufficient to clear the GE assembly when driving the saw to the cut position.	The clamp and clamp lever arm was modified to achieve the required travel distance.	FAT
	The linear actuator for the south clamp jaw structurally failed at its mounting points.	A new structure mount was fabricated and installed.	FAT
	The slippage of the drive wheel caused the saw to be incorrectly positioned for cutting operations.	The system was reprogrammed to eliminate the use of the motor resolver for positioning the saw and incorporate the use of proximity switches.	FAT
	The lifting features interfered with the mounting of the saw module.	The lifting features were repositioned to eliminate all interferences.	ESA

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Fines and Crud Collection Systems (WBS 1316 & 1317)	The fines collection hopper for the Upper Cutting System was too large to fit into the allocated space in the cell.	The hopper was redesigned to reduce its size to the minimum necessary to meet throughput.	ESA
Fuel Assembly Handling Fixture (WBS 1318)	Interferences existed between the FAHF and the PWR saddles on the Clamping Table. The open and closed positions of both the PWR and BWR FAHF were not achieved. Both the PWR and BWR FAHF interfered with the load cell assembly on the Off-Normal Table.	Both the FAHF and the saddles were modified. The short leg of the 'L' bracket of the handling fixture was notched to fit around the saddles and the saddles were machined to accept the long leg of the FAHF. The cam followers were repositioned and a new cam plate was fabricated and installed. The short leg of the 'L' was notched on both FAHF to fit around the assembly. In addition the load cell assembly fuel contact plate was reduced in size.	ESA SOT ESA
	The 'L' brackets on the PWR FAHF were not properly supported by the linear bearings.	The linear bearings were replaced with solid bronze sleeves.	PTC
	The 'L' bracket solid shaft support for the PWR FAHF failed in the area where the shaft diameter is reduced for mounting of the 'L' bracket.	The 'L' bracket support shafts were replaced with constant diameter shafts to eliminate stress concentrations.	ESA

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TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Fuel Assembly Handling Fixture (WBS 1318) continued	The tolerances between the RBT grapple plate and the FAHF support plate for both the PWR and BWR fuel types was too small for automatic operation to latch or unlatch the FAHF to the RBT.	Spacers were added under the latch pins to increase the clearances for automatic latching and unlatching operations.	ESA
	Interferences existed between the straight leg brackets, mounted on the south side of both the PWR and BWR FAHFs, and the Fuel Assembly Storage Rack vertical support structure.	The length of the straight leg brackets was reduced to fit between the storage rack vertical supports.	ESA
Clamping Table (WBS 1321)	A crud trap existed at the four Thompson rail cover plates.	A gasket was installed under each cover plate.	PTC
	An interference existed between the drive motor for positioning the upper PWR and BWR clamps and the Rod Consolidation Table.	The drive motor was repositioned at 90 degrees to its original position.	PTC
	The lower PWR clamps were not capable of producing their design clamping force.	The torque output was increased by replacing the integral gear reducer with a new gear reducer with a greater torque multiplier.	SOT
	A number of the locating pins for positioning the clamps on the table were improperly located.	All alignment pins were properly relocated.	ESA

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Clamping Table (WBS 1321) continued	The upper PWR clamps could not be positioned to clamp the first grid of the Westinghouse assemblies.	The programmed set point was changed so that the clamps gripped the second grid.	ESA
	The support frame for the upper PWR and BWR clamps was not properly positioned when installed.	The front edge of the base plate was machined so that it could be properly positioned.	ESA
	All loads were transmitted through the load cell assembly sensor diaphragm.	A round steel plate was installed on the load sensor to protect the diaphragm.	ESA
	The gear ratio for the position resolver was too small for absolute positioning.	The resolvers were regearred so that the resolver makes less than one revolution over the full length of travel of the system.	ESA
Rod Extraction System (WBS 1322)	The cables connected to the pull head carriage rubbed against the drive motor assembly housing.	The drive motor assembly was raised and the cables were passed under it.	PTC
	During operation the slack in the cables connected to the pull head carriage was too great.	Additional weight was added to each of the cable management systems.	PTC
	The grippers were not capable of providing the design holding force.	All of the Belleville washers were removed and the gripper holding force set for each gripper.	Bench Testing

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Rod Extraction System (WBS 1322) continued	The pull force readings from the pull head load sensors were inconsistent.	<p>The grippers which contained a load sensor were modified as follows:</p> <ul style="list-style-type: none"> o Installed needle bearings under the grippers o Added roller to back of grippers to prevent pivoting. o Changed pivot point to more uniformly load the needle bearings. o Removed tip for greater gripper opening. o Revised placement of lock nuts. o Removed socket nuts on non-load cell grippers o Added socket lock nuts on load cell grippers o Added stop pins in front of all grippers. 	Bench Testing
	<p>The roller screw became unstable at its specified operating speed.</p> <p>The ball lock feature for each gripper was not required because the release force was achieved without it.</p>	<p>The operating speed was reduced to where the roller screw remained stable.</p> <p>The ball lock assemblies were not installed in the pull heads</p>	<p>PTC</p> <p>Bench Testing</p>

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TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Rod Extraction System (WBS 1322) continued	The travel length of the cable management system pulleys was insufficient for the length of travel of the pull head carriage.	<p>The length of travel of the pulleys was increased as follows:</p> <ul style="list-style-type: none"> o The cable management system was repositioned higher on the cell wall. o The shaft supports for the pulley shafts were repositioned. o The length of the wire rope stretched between the two movable pulleys was increased. 	PTC
	The fuel rods were inserted into the grippers to a depth that prohibited them from being released when the 'REGrip' routine was executed.	A spacer rod was inserted into each gripper, which restricted the depth of insertion of the fuel rods.	SOT
	The timing band for the opening and closing of the grippers was too small, thus causing a fault condition.	The timing band for the operation of the grippers was increased to an acceptable span.	SOT
	The threads on the pull head mounting bolts engaged the back plate of the pull head frame when being loosened.	The diameter of the through hole in the back plate of the pull head was increased.	ESA

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Rod Compaction System (WBS 1323)	The rake did not close far enough below the smallest rod diameter for compaction operations.	Adjustable extensions were fabricated and installed onto each of the rake fingers.	PTC
	The side hold down rails were too heavy and became jammed, causing the fuel rods to bunch up.	Slots were machined into the hold down rails and the thickness was reduced. In addition, the mounting of the rails on the compaction system frame was changed from a floating design to a fixed design.	PTC
	The fuel rod, were able to ride under the east end of the rake during compaction operations.	A structural angle was bolted over the length of the support rail to increase the width of the rail supporting the east end of the fuel rods.	SOT
	The rod counters did not accurately count the fuel rods in the flat rod array transferred into and out of the compaction system.	The speed at which the fuel rod array was passed over the counters was reduced.	SOT
	The fuel rods bunched up under the side transfer fingers, causing inaccurate rod counts.	Spacer plates were fabricated and installed onto the finger module of the side transfer mechanism.	SOT
	The gate was not properly aligned with the rake do to warpage of the frame during welding.	Spacers were fabricated and installed to achieve proper alignment.	PTC

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Rod Loading System (WBS 1324)	The width of the gate knife blade was too large to properly segregate fuel rods.	The width of the knife blades were reduced by half.	PTC
	The loading of bowed fuel rods into a tightly packed triangular array in the loading system hopper was inconsistent.	The thickness of the slip sheets were reduced to less than the diameter of the smallest fuel rods to control the positioning of the rods.	SOT
	The pusher drive screw was unstable at the selected operating speed.	The speed of the pusher was reduced to an acceptable limit.	ESA
	The rod pusher was not capable of pushing the reconfigured fuel rod bundle into the fuel canister beyond the depth of the canister lid.	A spacer was fabricated and installed on the pusher plate.	PTC
	The hopper elevation drive was not capable of lifting the weight of the reconfigured fuel rod bundle.	A larger motor was installed on the elevation drive system.	SOT
	The gate drive motor slipped from the roller screw at its end of travel in JOG mode, disengaging the resolver and motor from the drive system.	The roller screw was pinned to the motor drive shaft and travel limits were established for JOG mode operations to protect the drive system. The same fixes were incorporated into the rake drive system.	SOT

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Rod Consolidation Table (WBS 1325)	No problems were encountered.	None	NA
Fuel Canister Upender (WBS 1331)	<p>The fuel canister was positioned too low for proper interfacing with the Rod Loading System hopper.</p> <p>The clamp arm pivot shafts galled, causing the drive motor to torque fault when operation was attempted.</p> <p>Based on the operation of the Downender, there was a potential for the movable frame support bearings to slip relative to the stationary base frame.</p>	<p>Spacer plates were fabricated and installed on the vertical supports for the movable frame.</p> <p>The clamp assembly was modified to eliminate galling as follows:</p> <ul style="list-style-type: none"> o Grease grooves were cut into the pivot shafts. o Each pivot shaft was plated. o Grease fitting were installed as required. o Bronze washers were installed between movable components and the stationary components of the clamp assembly. o Locking rings were installed at each end of the pivot shafts. <p>The support bearings were mounted into recesses machined into their mounting surfaces.</p>	<p>ESA</p> <p>PTC</p> <p>FAT</p>

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Fuel Canister Upender (WBS 1331) continued	There was an interference between the main drive assembly and the vertical support for the movable frame.	The main drive system base plate was notched to fit around the vertical support.	ESA
Fuel Canister Closure System (WBS 1332)	Not applicable - the closure system was GFE.	Not applicable	NA
Fuel Canister Storage Rack (WBS 1333)	None	None	NA
Fuel Canister Grapple (WBS 1334)	The fuel canister support knob did not fit into the grapple hook recess.	The grapple hook recess was enlarged to accept the lifting knob.	FAT
NFBC Canister Loading System (WBS 1341)	The system was warped as a result of the welding during fabrication. NOTE: This system was excluded from testing due to the refocusing of the test program.	The loading system was ground and shimmed as required so that the system was properly installed.	Install
NFBC Canister Upender (WBS 1342)	The drive motor was not capable of rotating the movable frame under worst case load conditions.	The drive motor was replaced with a larger drive motor.	FAT
NFBC Canister Closure (WBS 1343)	Not Applicable - the closure system was GFE.	Not applicable	NA

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TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
NFBC Storage Rack (WBS 1344)	None	None	NA
Waste Container Transfer Fixture (WBS 1351)	None	None	NA
Off-Normal Station (WBS 1352)	Based on the operation of the cutting station clamps, there was a potential for the roller screw to become damaged and the fuel to be caught in the grid support.	Hard stops were added to prevent damage to the screw and steel plate caps were installed on the grid support to permit the assembly to slide when being centered.	ESA
Equipment Storage Rack (WBS 1353)	The load cell assembly interfered with the FAHF when placing a fuel assembly onto the table.	The FAHF 'L' bracket was notched and the load cell assembly fuel contact plate was reduced in size.	ESA
RM-10A Manipulator (WBS 1354)	None	None	NA
Robotic Bridge Transporter (WBS 1214)	The manipulator did not operate through its full range of motions for all axes.	The manipulator was set up to have protective sleeves over each arm for decontamination purposes, which reduced the range of motion. The procedure was corrected for this discrepancy.	SOT
	The RBT cables interfered with the lights and cameras mounted on the north wall of the cell.	The cameras and lights were recessed into the wall.	PTC

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Robotic Bridge Transporter (WBS 1214) continued	The RBT was not capable of being properly positioned. The RBT did not shut down prior to engaging the hard stop when the end-of-travel limit switch was activated.	The software was updated to provide adjustment capability to each axis before a fault condition was generated. The resolver chain drives were also improved by providing for the capability to tighten the chain, eliminating drive system slop. New limit switch brackets were fabricated and installed to position the sensor further from the RBT frame.	ESA PTC
Manipulator Transporter (WBS 1215)	The MT did not shut down prior to engaging the hard stop when the end-of-travel limit switch was activated.	New limit switch brackets were fabricated and installed to position the sensor further from the MT frame.	PTC

TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Control System (WBS 15121)	<p>Software:</p> <ul style="list-style-type: none"> The operator station control screens were not properly synchronized. Under load, RBT's telescopic tube faulted. <p>The Control System's retry function or the incremental move on the RBT was not functioning as expected.</p> <p>Hardware:</p> <ul style="list-style-type: none"> Proximity Sensor Abundance of surrounding metal. 	<p>The Control System generation was reconfigured to correct problem.</p> <p>The average and peak current limits were raised to their maximum allowable for motor operations.</p> <p>Modifications to the UCMOS Executive software program were implemented to correct the incremental move.</p> <p>This problem was resolved by one of the following:</p> <ul style="list-style-type: none"> Change material of bracket to one that is less sensitive. Relocate sensor to an area with less surrounding metal. Turn sensitivity of controller to work to a minimum target distance (1/8 inch). <p>This problem was resolved by decreasing the gap to 1/8 inch and reducing sensitivity.</p>	SOT

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TABLE 5.0 - SYSTEM PROBLEMS ENCOUNTERED

SYSTEM	PROBLEM	SOLUTION	SOURCE
Control System (WBS 15121) continued	Hardware (continued): RBT's bridge faulted at full speed.	The isolation transformer feeding the servo-drive power supply was rewired to provide a higher bus voltage to the RBT drive amplifiers.	PTC
Cell Surveillance System (WBS 151222)	Camera and lights assemblies on north wall interfered with RBT and M. operations. Failure of capacitors in the video control receivers at the Video Control Cabinet. Capacitors were determined to be of a lower quality. Overlapping and duplicate screen display on video monitors.	Camera and lights on north wall were recessed into the wall to prevent interferences. All failed capacitors were replaced and no failure occurred among the replaced capacitors. Data were acceptable for test verification. Changes were set to be made on Diamond's software.	PTC

6.0 FUNCTIONAL REQUIREMENTS CONFIRMATION

This section provides a summary overview of the Phase III test program versus the project requirements. It identifies all the testing developed to verify both the Generic and TAN specific functional requirements and the contractual requirements. This section also provides a summary of the results obtained during testing and identifies the associated references.

The information provided in this section is presented in tabular form. This approach was taken for the ease of assimilating all of the test data. Table 6.0-1 provides a summary of the test results versus the functional requirements. Table 6.0-2 provides a summary of the test results versus the contractual requirements. The results of the time study versus the exact times measured during testing are provided in Table 6.0-3. A more detailed description of the results of all of the testing performed is provided in Appendices I-4.1 through I-4.25 to this volume of the Final Report.

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>1. The system shall consolidate 750 metric tons of heavy metal (MTHM) of spent fuel per year based on a 60/40 split between PWR/BWR fuel types. This throughput is to be based on a 75% availability for two shifts per day (16 hrs.) five days per week over a 30-year life.</p>	<p>Integrated System Testing was identified to verify system performance and record the elapsed time to perform process steps for normal, off-normal, and maintenance operations. These tests used mock-up fuel assemblies of the W 17x17, W 15x15, B&W 15x15, and GE 8x8 fuel types. These process times were used to update the throughput analysis.</p>	<p>The normal IST for the W 17x17 fuel type was the only test sequence performed. All normal IST for the other fuel types, off-normal IST, and maintenance IST were not performed due to the refocusing of the test program. The W17x17 fuel type was selected because this fuel requires the greatest amount of time to process. The results of this test demonstrate that the system as presently configured is not capable of processing the required number of assemblies per day to meet the throughput. The time required to prepare the fuel assembly for rod extraction exceeded the allotted time of 146.4 minutes by a factor of 1.85.</p>	<p>9315-TP-215A 9315-TP-215 9315-TP-216 9315-TP-217</p> <p>NOTE: Test procedures 216 and 217 were not issued. Refer to 9315-TAC-216 and 217 for an overview of these tests.</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>2. As a minimum the system must package all fuel rods from two PWR or four BWR assemblies into one fuel canister of either a square or round geometry.</p>	<p>System Operational Tests were identified to verify the rod loading system/fuel canister interface for both the square and round canister geometries, reference 9315-TP-207. In addition, Integrated System Testing was identified to verify that the system could load a full complement of fuel rods from two PWR assemblies (W 17x17, W 15x15, and B&W 15x15) and four BWR assemblies (GE 8x8), (reference 9315-TP-215).</p>	<p>The System Operational Test of the Rod Loading System included several test sequences to ensure the proper loading of the fuel rods into a square canister. The results of this test sequences are as follows:</p> <ul style="list-style-type: none"> o The position of the canister was verified to be aligned with the rod loading system. o The pusher drive system operational force was measured to verify that it exceeded the frictional force due to the weight of the consolidated rod bundle. o The loading of multiple rows of mock-up fuel rods into a square canister was performed and observed. <p>In addition, a full complement of test rods (528) from two W 17x17 mock-up assemblies was observed being reconfigured and loaded into a square canister. All tests identified for the other PWR fuel types and the BWR fuel type were not performed due to the refocused test program.</p>	<p>9315-TP-207 9315-TP-215 9315-TP-215A</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>3. The system shall be capable of consolidating any type of PWR or BWR fuel used in the United States LWR industry that will exceed 1% of the fuel inventory at the year 2000.</p>	<p>System Integrated Testing was identified to test operations to set up the equipment for four different fuel types and demonstrate consolidation operations on these fuel types (reference 9315-TP-215).</p>	<p>The setup of the equipment and demonstration of consolidation operations was performed on the W 17x17 fuel type only. Testing of the other fuel types, the W 15x15, B&W 15x15, and GE 8x8, were not performed due to the refocusing of the test program. As a result of this test sequence, it was successfully demonstrated that the equipment could be manually setup and operated to consolidate W 17x17 fuel. Even though testing did not fully demonstrate the other fuel types, there were no results that would question that the system is capable of meeting this requirement.</p>	<p>9315-IST-215A</p>
<p>4. The system shall operate on a continuous basis during the operational period defined as two shift/day and five days per week.</p>	<p>This requirement is validated by design review and not by any testing identified for this phase of the program.</p>	<p>NA</p>	<p>NA</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>5. The system shall operate remotely during normal and off-normal operations. The system shall be semi-automatic or full automatic.</p>	<p>System Operational Testing (SOT) for each piece of system equipment has been identified to ensure that each can be operated in a semi-automatic mode of operation. In addition, an Integrated System Test (IST) was identified to verify that all of the equipment would operate as a system in the semi-automatic mode of operation. Both test series (SOT and IST) verified the equipment and integrated system for both normal and off-normal conditions.</p>	<p>All equipment was qualified for semi-automatic operations during the individual equipment SOTs. All equipment was tested to ensure that each subsystem could be successfully operated in the modes of operation available. Once this test sequence was completed, all equipment subsystems were operated as a unit to verify that each piece of equipment would operate in its predefined sequence. This test sequence verified both normal and off-normal modes of operations for the equipment. With the completion of these test sequences, all of the equipment was tested as an integrated system for normal fuel process operations. In all test sequences all of the equipment, individually or as a unit, was capable of being operated remotely in the automatic mode of operation. The test sequence for verifying system operations for off-normal conditions was not performed due to the refocusing of the test program.</p>	<p>All equipment SOTs, refer to Appendices I-4.1 through I-4.23, of this report.</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>6. The system shall provide for the remote monitoring of operations from the control panels. Monitoring shall include audio and video monitoring of the equipment operations, and monitoring of the system operations by instrumentation and alarm.</p>	<p>System Operational Tests have been identified for each of the system equipment to verify the following:</p> <ul style="list-style-type: none"> o Operation of all equipment sensors (proximity switches, load cells, resolvers) o Proper control system response (alarm, system shutdown, etc.) to the sensor readings. o Proper video call up and camera display for monitoring functions and off-normal conditions. o Proper control system/equipment interfacing during normal and off-normal conditions. o Proper function of software interlocks. o Proper generation of reports (failures, hold points, fuel movement, and test data). <p>This testing was identified for both the component level and the system level.</p>	<p>All equipment required for the refocused test program has successfully demonstrated the ability to meet this design requirement. All of the equipment tested has been able to be monitored for startup, travel distance, position, speed, and shutdown for normal operations. In addition, these systems were able to be monitored for over travel, torque faults, positional errors, and interface errors for off-normal operations.</p>	<p>All equipment SOTs (refer to Appendices I-4.1 through I-4.22) and IST (Appendix I-4.23).</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
7. The system shall minimize the volume of secondary wastes generated by the consolidation process and the dispersion of radioactive crud, fines, and cuttings. The system shall minimize the generation of liquid waste.	Phase II	NA	NA
8. The system shall provide for the collection and control of all radioactive crud, fines, cuttings, and fuel pellets and/or fuel pellet powder as may be generated.	System Operational Tests have been identified for the various waste collection systems developed for the system. These tests were established to evaluate the effectiveness of these systems for collecting the waste products and removal of these waste products from the process cell.	All testing associated with the waste collection and disposal systems was eliminated from the Phase III Test Program when it was refocused for testing only that equipment necessary in demonstrating the consolidation of the W 17x17 fuel type.	Appendix I-4.8 Appendix I-4.9 Appendix I-4.15
9. The system shall provide for the remote tooling changes, remote maintenance, remote component replacement, and remote decontamination of all consolidation and supporting equipment.	Both System Operational Testing and Integrated System Testing have been identified to demonstrate that the rod consolidation system meet these requirements for all but remote decontamination of the equipment. The requirement for the decontamination of the equipment was eliminated from the project requirements (refer to the Phase III contract).	All testing (both SOTs and ISTs) for demonstrating remote tooling, components, and equipment replacement was eliminated from the Phase III test activities when the test program was refocused to demonstrate processing of the W 17x17 fuel assemblies.	Appendix I-4.15 Appendix I-4.25

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
10. The system shall permit and facilitate accountability for all special nuclear materials during the consolidation process. Accountability shall be provided for intact fuel rods, broken fuel rods, and fuel pellets and parts thereof.	Integrated Systems Testing has been identified to demonstrate the accountability of special nuclear material for the system. These tests qualify the system for tracking intact fuel rods, fuel pellets, and parts thereof (reference Appendices I-4.23 & I-4.24).	The only test completed for Phase III of the project, due to the refocusing of the test program, was the normal Integrated System Test. This test demonstrated the ability of the system to account for fuel assemblies and intact fuel rods as they were manipulated through the process cell. The system demonstrated the ability to track and account for all fuel assemblies, all fuel rods, and all NFBCs from cell loading to cell unloading operations.	Appendix I-4.23
11. The system shall maintain K less than 0.95 for all normal and off-normal conditions.	Analyses.	NA	NA

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>12. The system shall minimize the potential for the pyrophoric ignition of zirconium or any of the materials capable of ignition.</p>	<p>The primary method of validation was by design review. However, normal Integrated System Testing and System Operational Testing of both the Cutting Systems and Chip Collection System provided an opportunity to observe and evaluate the processing of these pyrophoric materials.</p>	<p>During the performance of each of these tests, the system was monitored for pyrophoric ignition of the zirconium. In all tests there were no problems observed with the potential of the pyrophoric ignition of the zirconium chips during cutting of the upper end fitting or extraction of the fuel rods from the assembly. There were no observable sparks, flashes, or any other indication of a potential ignition of the hazardous materials.</p>	<p>Appendix I-4.8 Appendix I-4.11 Appendix I-4.23</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>13. The system shall minimize the occurrence of and demonstrate the ability to recover from off-normal events occurring in the consolidation of spent fuel rods. Such events that shall be identified by the contractor should include:</p> <ul style="list-style-type: none"> - handling and packaging of partially disassembled fuel assemblies - rod rupture - rod sticking during disassembly - recovery of dropped fuel pellets - recovery of fissile material in the form of fines - fire - equipment breakdown and repair - loss of electrical power and other utilities - loss of ventilation 	<p>Both SOTs and ISTs have been identified to verify the system capability to recover from off-normal and maintenance events. Each SOT tested the equipment for response to a failure condition during operation. In addition, the SOTs tested equipment response to interlock faults. Two ISTs were identified for testing fault conditions dealing with the processing of the fuel and the maintenance IST tested the system for recovery from fault conditions dealing with the operation of the equipment.</p>	<p>All equipment required to support the consolidation of the W 17x17 fuel type was tested for proper response and recovery from a fault condition. Each piece of equipment was operated and a drive system fault introduced during operations. In all cases the drive system deactivated in a safe condition, and the Control System provided the proper warnings and alarms. All systems were capable of being recovered from the Control System and sequential operation continued. Neither the off-normal or the maintenance ISTs were performed due to the refocusing of the test program. Therefore, no results were obtained on the recovery of the system from failures that occurred in the act of processing fuel or on the repair of equipment.</p>	<p>All Appendices I-4.1 through I-4.22. Appendix I-4.24 Appendix I-4.25.</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
14. The system shall meet the requirements of quality assurance standards established in ASME/ANSI-NQA-1 (1986) with addenda.	Design and project audits.	NA	NA
15. The system shall include all equipment for the handling of materials, components, various spent fuel assemblies, and containers.	Two tests have been identified to demonstrate the ability of the system to meet this requirement to the extent specified by the contract. One test (SOT 9315-TP-207) demonstrates the ability of the system to accommodate a round canister. The second test (IST 9315-TP-215) demonstrates the ability of the system to accommodate different fuel types, handle all of the materials transfer operations, and handle all fuel and canister transfers.	None of the testing that pertains to this requirement had been performed due to the refocused test program. The system was manually set up for one fuel type (W 17x17) and tested for consolidation of that fuel type. All support functions were eliminated from the test.	Appendix I-4.7 Test Procedure 9315-TP-215
16. The system shall minimize the external contamination of the consolidation canister during all operations involved in the consolidation process.	Design review	NA	NA
17. The system shall be capable of being installed within an enclosure with the dimension of 20' wide x 55' long x 31' high.	Installation of the test equipment at the test facility.	NA	NA

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
18. The system shall be capable of maintaining the fuel rod cladding temperature equal to or less than 175 degree C while exposed to air. The maximum canister thermal loading shall be 2KW.	Analysis	NA	NA
19. The system shall accommodate fuel canisters with lengths of 171 ± 0.1 inches.	SOT 9315-TP-207 and IST 9315-TP-215 were identified to test the system for the loading of both the 161 inch and the 171 inch square canisters.	As a result of the refocusing of the test program, the 171 inch canister was not tested. The 161 inch square canister was only canister tested.	Appendix I-4.7 Appendix I-4.23 9315-TP-207 9315-TP-215
20. The system shall provide storage capacity for empty and loaded consolidated fuel rod canisters and NFBC canisters sufficient to support two continuous shifts of operations. A 'clean' environment shall be maintained in the consolidated fuel rod container and NFBC container storage area for empty and loaded containers.	Design review	NA	NA

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>21. The system shall provide for the closure of the loaded canister. The closure system shall provide a closure that is capable of maintaining the fuel rods within the canister. If the closure involves the canister lid, the closure shall be of sufficient strength to support the weight of the loaded canister. If welding is used for the closure of the loaded fuel canister, the system shall provide for the nondestructive examination of the weld(s).</p>	<p>The design and structural verification of the canister closure system for the fuel rod canister was the responsibility of DOE. However, the fit up and function of the closure system was tested during cold checkout testing.</p>	<p>The canister closure system was verified during the cold checkout testing of the equipment. As part of the testing of the fuel canister upender (9315-TP-206), the fit up of the closure lid to the canister grapple and canister was verified. As a result of this test, the lid needed to be modified. This modification reduced the gap between the lid and canister to ensure that the lid could not become inadvertently disengaged from the canister. In addition, the canister grapple had to be modified to properly interface with the canister lid. When this testing was completed and the fixes made, the canister closure system was tested as part of the modified normal IST (9315-TP-215A). This test demonstrated the ability of the canister closure to support a loaded canister.</p>	<p>Appendix I-4.6 Appendix I-4.23</p>
<p>22. The system shall operate on a batch basis for the hot demonstration.</p>	<p>Design review</p>	<p>NA</p>	<p>NA</p>

TABLE 6.0-1: SUMMARY OF TEST RESULTS VERSUS FUNCTIONAL REQUIREMENTS

GENERIC/TAN FUNCTIONAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS	REFERENCE
<p>23. The system shall provide for the placing of the non-fuel-bearing component's into a container. The skeleton may or may not have a lower end fitting attached.</p>	<p>Testing has been identified for the qualification of the equipment required to meet this function. The testing has been divided into two tests. The first test (SOT 9315-TP-505) verified the interface between the NFBC loader and the NFBC canister. The second test (IST 9315-TP-215) verified the operation of this equipment as part of the overall system operation.</p>	<p>None of the testing associated with the NFBC equipment was performed due to the refocused test program. However, it was demonstrated the non-fuel-bearing component can be transferred to the NFBC loading system as part of the modified IST (9315-TP-215A).</p>	<p>Appendix I-4.4 Appendix I-4.13 Appendix I-4.23 9315-TP-215</p>
<p>24. The system shall be capable of being installed in the TAN enclosure.</p>	<p>Design review (Task #8).</p>	<p>NA</p>	<p>NA</p>

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TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
1. Demonstrate square fuel rod reconfiguration and loading	<p>Two test sequences have been defined to demonstrate this requirement as follow:</p> <ul style="list-style-type: none"> - SOT 9315-TP-207 demonstrated the loading of the square hopper and square fuel canister using a total of 68-0.375 inch simulated fuel rods. - IST 9315-TF-215A demonstrated the loading of the square hopper and square fuel canister using a full complement (528) of 0.375 inch simulated fuel rods. 	<p>In both tests the system successfully reconfigured all simulated fuel rods into a square bundle and loaded them into a square fuel canister (reference Appendices I-4.7 and I-4.23). In addition, the IST demonstrated the ability of the system to achieve a 2-1 consolidation of the W 17x17 fuel rods. All other tests identified for the other fuel types were not performed due to the refocusing of the test program.</p>
2. Demonstrate round fuel rod reconfiguration and loading	<p>Testing was identified (reference 9315-TP-207) to demonstrate the loading of fuel rods into a round hopper and subsequent loading of the round fuel rod bundle into a round canister.</p>	<p>This test sequence was not performed as part of this phase due to the refocusing of the test program.</p>

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
3. Cooling system and temperature monitoring systems will be tested in Phase III; however, actual thermal verification measurements cannot be performed until Phase IV.	Testing was identified to verify that the temperature monitors were properly installed, calibrated, and hooked up to the Control System (reference 9315-TP-601). No additional testing of the cooling system was performed during this phase of the program.	All temperature monitors were found to be properly installed and functioning within the manufacturer's specified limits.
4. Provide for the testing of the following mock-up fuel assembly types: <ul style="list-style-type: none"> - CE 14x14 - W 15x15 - W 17x17 - B&W 15x15 - GE 8x8 	All equipment SOTs were set-up to test all parts of the equipment and the interface to the control system for each of the fuel types identified. In addition, the normal IST was set up to test all fuel types except the CE 14X4 (one at a time) from loading of the fuel into the process cell to removing the canistered reconfigured fuel rod bundles (reference IST 9315-TP-215).	The test program was refocused to test all systems required to process only the W 17x17 fuel types. As a result all testing for the other fuel types was not performed for the majority of the equipment (SOTs) and not performed at all for the IST. However, the equipment that was tested for other fuel types (Fuel Assembly Storage Rack, Staging/Cutting Station, and Off-Normal Station) successfully demonstrated the ability of the system to be changed over for the different fuel types.

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
5. Provide video/photographic record of all integrated and off-normal tests.	NA	NA
6. The test program shall demonstrate the handling of the following: <ul style="list-style-type: none"> - intact fuel assemblies - unloaded/loaded fuel canisters - replacement parts - waste containers - all other support materials 	The IST identified for this phase of the program demonstrated these requirements. The normal IST required the handling of intact fuel assemblies, unloaded fuel canisters, loaded fuel canisters, and waste containers. The off-normal and maintenance ISTs required the handling of individual fuel rods, spare parts, waste containers, and failed components (reference 9315-TAC-215, 9315-TAC-216, and 9315-TAC-217).	As a result of the refocused test program, the majority of the tests identified to meet this requirement were not performed. A scaled down version of the normal IST was performed, successfully demonstrating the handling of intact fuel assemblies, loaded fuel canisters, and unloaded fuel canisters (refer to Appendix I-4.23). All handling operations were able to be performed as designed.
7. Functional testing shall include testing and evaluation of normal, off-normal, & maintenance operations and recovery from off-normal events.	Three test sequences were established to demonstrate each of these modes of operation (reference 9315-TAC-215, 9315-TAC-216, and 9315-TP-217). These tests were to provide a comprehensive evaluation of the system.	As a result of the refocusing of the test program, the only testing performed was a scaled down version of the normal IST. This test successfully demonstrated the normal processing of the W 17x17 fuel only (reference Appendix I-4.23). All other support functions were eliminated.

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
8. Functional testing shall provide for the qualification of the rod consolidation system and subsystem production capacity.	Testing required the collection and evaluation of the elapsed times to complete all system (IST) and subsystem (SOT) operations and tasks.	<p>The amount of data collected during Cold Checkout Tests was significantly reduced. The refocused test program focused on qualifying the production capacity of the system for the worst case fuel type (W 17x17). As a result, no data were collected to qualify the times defined for off-normal and maintenance events. The results of the testing completed demonstrated that the elapsed time to perform the various tasks for processing the W 17x17 fuel were on an average of 1.2 to 1.8 times greater than predicted. This is a result of three conditions: 1) the size of the process cell, 2) the design of the drive systems, and 3) Upper Cutting system tool life vs cutting speeds. Therefore, the system is not capable of meeting the production requirement for the W 17x17 fuel types as presently configured.</p>

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TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
9. Functional testing shall provide for the qualification of operating and maintenance personnel requirements for the Rod Consolidation System.	<p>Three tests have been identified to qualify the requirements for operating personnel under each mode of operation. These tests are as follow:</p> <ul style="list-style-type: none"> o Normal process operations (reference 9315-TP-215 and 9315-TP-215A). o Off-normal process operations (reference 9315-TP-216). o Maintenance operations (reference 9315-TP-217). 	<p>Due to the refocused test program, only the normal process operations for the W 17x17 fuel were tested (reference 9315-TP-215A). As a result, the requirements for operating personnel were qualified for normal fuel process operations only. The minimum number of operators required during normal operations was as predicted - three.</p>
10. Functional testing shall provide for the reliability, availability, and maintenance assessment by system and component.	<p>The primary method for validating this requirement was by analysis. However, the test program was set up to collect test data to verify some of the analytical data. All system SOTs measured the elapsed time for all equipment drive systems to perform their function. In addition, all of the ISTs measured the elapsed time of the system to perform specific process steps.</p>	<p>Neither the off-normal IST or maintenance IST was performed. In addition, normal fuel process operations were conducted only for the W 17x17 fuel type, and the only SOTs completed were for those systems required to support this test. As a result there were insufficient data to complete a detailed RAM assessment of the system based on test results.</p>

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
11. Functional testing shall provide for the verification of the safety system performance.	Numerous test sections have been identified to verify the performance of the safety systems defined for the process system. All of the equipment SOTs tested sensor operations and equipment software interlocks. The off-normal IST (9315-TP-216) was to test system responses to both equipment and fuel type failures to ensure safe shutdown. In addition, the Control System SOT (9315-TP-601) tested all of the equipment designed into the cell for safety considerations (i.e., smoke detectors, thermal sensors, radiation detectors, etc.).	<p>All of the equipment required to support the processing of the W 17x17 fuel was tested successfully for the following safety considerations:</p> <ul style="list-style-type: none"> o equipment interlocks o operational hold points o drive system fault o sensor operations o break away force for the W 17x17 pull heads o load rating o emergency stop control o fuel handling operations <p>Due to the refocused test program, the system was not tested for responses to off-normal events.</p>

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TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
12. Functional testing shall provide for the verification of the adequacy of the component, subsystem, and system interfaces, including measurement and definition of interface tolerances.	<p>The SOTs have been developed to verify the following:</p> <ul style="list-style-type: none">o That the components are properly assembled per the design drawings and perform per manufacturer's specifications.o That the equipment subsystems are properly assembled and installed per the design drawings and perform as designedo That the equipment has been properly installed to interface with the other equipment within the cell. <p>The normal IST for the W 17x17 fuel assemblies confirmed the above test results.</p>	<p>As a result of the SOTs for the equipment and the IST, it has been verified that all of the interfaces were within tolerances for processing W 17x17 fuel assemblies. The results of the measurement of all of the interfaces practical are provided in the record copy of the respective test procedures.</p>

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
13. Functional testing shall provide for the measurement and definition of utilities.	The primary method of defining the utilities for the process equipment is by analysis. However, the test program was set up to measure and define these utilities. The equipment SOTs measured and recorded the current and voltage for each of the drive systems. In addition, the ISTs quantified the utilities required to support process operations.	Several problems were encountered during testing. The torque of the servo-drive motors could not be measured due to the nature of these motors. Instrumentation for measuring these parameters for these types of motors does not exist. In addition, the integrated system testing was significantly reduced to eliminate all efforts not required to demonstrate processing of the W 17x17 fuel types. As a result, no meaningfully data could be obtained.
14. Functional testing shall provide for the definition of the waste stream composition and waste volumes to the extent practical in Phase III.	The normal IST provides for the collection and evaluation of the waste streams (crud, fines, water, filters, cutting tools, and NFBCs).	Due to the refocusing of the test program, most of the operations that would enable the waste streams to be monitored were not performed. As a result, only the fines generated during cutting operations could be collected and evaluated.

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
<p>15. Functional testing shall provide for the verification of the performance of the data acquisitions systems including parameter identification and accuracy of measurements for:</p> <ul style="list-style-type: none"> o Rod pull forces o Accountability o Cutting fines o Throughput o Temperature 	<p>Rod pull force data was verified as part of the extraction system SOT (9315-TP-201) and the normal IST (9315-TP-215A). The accountability data and throughput data were verified as part of the normal IST (9315-TP-215A). The cutting fines data were supposed to be verified as part of the waste collection system SOTs (9215-TP-208A, B, and C) and the normal IST (9315-TP-215A). The accuracy of the temperature data was verified by analysis. The accuracy of the temperature monitors was verified as part of the control system SOT (9315-TP-601).</p>	<p>As part of the Extraction system SOT, a known force was applied to each W 17x17 pull head gripper that contained a load cell. The readings from each pull head load cell were then compared to this known force. These readings were inconsistent and not repeatable for all of the pull head grippers tested. The same inconsistency was observed during IST. The accountability system functioned as designed but had three minor problems as follows:</p> <ul style="list-style-type: none"> o Serial number did not clear from simulated RBT 2 once fuel canister was placed into the storage rack. o Serial numbers appeared in wrong fuel canister and NFBC canister storage cell when these canisters were moved to storage from their respective Upenders. Serial # didn't clear when the NFBC Loader was empty.

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
15. continued		<p>Throughput data were collected during the normal IST testing. A comparison to the expected results indicates that, for the W 17x17 fuel type, each process step takes 1.2 to 1.8 times longer than estimated.</p> <p>The test identified to quantify the ability of the system to handle waste generated during process operations was not performed due to the refocusing of the test program. However, samples were collected during the modified IST (refer to Item 14 above).</p> <p>Tests were specified to verify the setup and accuracy of the temperature monitors. In all cases each temperature monitor functioned within manufacturer's specifications when installed.</p>
16. Functional testing shall verify Accountability System performance.	Refer to item 15 above.	Refer to item 15 above.

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TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
17. Functional testing shall verify the performance of crud control and collection system, fines control and collection system and pyrophoricity control system to the extent practical in Phase III.	SOTs 9315-TP-208A, B and C were identified to qualify the waste collection system.	The SOTs identified for the waste collection system were not performed due to the refocusing of the Phase III test program.
18. Functional testing shall verify the performance of the system to be reconfigured to accommodate different types of PWR and BWR fuel assemblies	IST 9315-TP-215 was identified to demonstrate this requirement.	Testing of system change over was not performed due to the refocusing of the test program.
19. Functional test shall verify the performance of the system to be changed over from square to round consolidated fuel geometries.	SOT 9315-TP-207 was identified to demonstrate this requirement.	Testing of system change over for different consolidation geometries was not performed due to the refocusing of the test program.

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
20. Functional testing shall verify the performance of the control system and system software.	All SOTs and ISTs identified as part of the Phase III test program demonstrate this requirement.	The Control System and the system software performed as designed for normal system operations and for drive system fault conditions. Off-normal and maintenance operations were not verified due to the refocusing of the Phase III test program.
21. The contractor shall evaluate the performance of the system at the completion of Phase III testing and identify design improvements which significantly increase system performance and/or reliability.	NA	NA
22. NUS will perform additional testing of the internal diameter tube cutters. An end mill and an expansion reamer type cutter will also be tested if necessary.	Bench testing was performed.	Reference NUS document NO. 9315-M-219.

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
23. The contents of the Phase III test cell and their locations will be essentially identical to the Phase IV systems for the items within the NUS scope and supply.	NA	NA
24. Conduct a Readiness Review prior to Integrated Systems Testing and informal Readiness Review in accordance with Engineering Division Procedures.	Not applicable	Not applicable
25. Consolidate B&W 15x15 fuel types into a square canister configuration	Normal IST 9315-TP-215 was identified to consolidate the B&W 15x15 type fuel assembly into a square canister.	Testing of the B&W 15x15 fuel assemblies was not performed due to the refocusing of the Phase III test program.
26. NUS shall test maximum packing methods for round and square canisters.	Normal IST (9315-TP-215) for the GE 8x8 type fuel assemblies was identified to demonstrate maximum packing of a square canister. SOT 9315-TP-207, Section 8.5.17.6 was identified to demonstrate maximum packing of the round canister.	Neither of these two tests were performed due to the refocusing of the test program.

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TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
27. Analyze and program CCTV cameras prior to testing.	A CCTV coverage assessment analysis was performed and all SOTs performed verification of camera coverage and programmed "CALL" functions.	Each SOT performed tested the "CAMERA CALL" function for fault conditions and hold points and evaluated camera coverage in performing its function. In all cases the "CAMERA CALL" functions operated as designed and adequate coverage of the system could be provided to perform a specific task.
28. Design and test portable and fixed HEPA filters in accordance with ANSI N509-1975, ANSI N570-1980, ERDA 76-21, and ACGIH Ventilation Handbook requirements.	Design review	NA
29. Test vacuum system design for lifting pellets.	SOT 9315-TP-208A&B was identified to test the vacuum system.	This test was not done due to the refocused test program.
30. Test Fuel Canister Upender ability to handle both long and short fuel canisters.	SOT 9315-TP-206 tested the long (171") canister and IST 9315-TP-215A tested the short (161") canister.	The Fuel Canister Upender was able to be manually modified to accommodate either length of canister.

TABLE 6.0-2: SUMMARY OF TEST RESULTS VERSUS CONTRACTUAL REQUIREMENTS
SECTION C & SECTION J ATTACHMENT 3 OF THE CONTRACT

CONTRACTUAL REQUIREMENTS	VALIDATION METHOD	TEST RESULTS
31. Test generic loading of the round canister and analyze the effects on throughput.	SOT 9315-TP-207, Section 8.5.17.6 was identified to meet this requirement.	This test was not performed due to the refocusing of the test program.
32. Vacuum procedures for zirconium particles shall be developed including off-normal procedures to be followed in the event of a flash fire in the vacuum system.	ISTs 9315-TP-215, 9315-TP-216, and 9315-TP-217 were identified to test the procedures developed for the vacuum and safety systems.	None of these tests were done due to the refocusing of the test program.
33. The results of the updated throughput analysis shall be incorporated into the Phase III test procedures.	The updated throughput analysis results were incorporated into each IST procedure as acceptance criteria.	NA

TABLE 6.0-3: SUMMARY OF TEST RESULTS VERSUS THROUGHPUT ANALYSIS

OPERATIONS	CALC. TIME MINUTES	MEAS. TIME MINUTES	COMMENTS
Fuel Assembly Preparation			
1. Transfer 1st assembly to cutting station.	3.5	8.73	Additional move required by RBT due to proximity of equipment.
2. Cut end-fitting from 1st assembly.	65.9	86.36	Cut time can be reduced at the expense of tool blade life.
3. Transfer 1st assembly to clamping table.	3.8	4.00	
4. Transfer 2nd assembly to cutting station.	3.5	5.27	Additional move required by RBT due to proximity of equipment.
5. Cut end-fitting from 2nd assembly.	65.9	94.88	Same comment as #2 above.
6. Transfer 2nd assembly to clamping table.	3.8	5.75	
***** SUBTOTAL *****	146.4	204.99	*****
Rod Compaction System			

TABLE 6.0-3: SUMMARY OF TEST RESULTS VERSUS THROUGHPUT ANALYSIS

OPERATIONS	CALC. TIME MINUTES	MEAS. TIME MINUTES	COMMENTS
1. Fuel rod extraction, compaction, and hopper loading of 528 fuel rods.	105.2	272.2	Extraction drive system forced to operate at reduced speed due to oscillations in drive shaft at design speeds.
2. Fuel canister loading.	3.3	Not meas.	Rod pusher drive system forced to operate at a reduced speed due to oscillations in drive shaft at design speeds.
***** SUBTOTAL *****	108.5	>272.2	*****
Fuel Canister Preparation			
1. Upend fuel canister	<5.0	3.65	
2. Canister closure	2.1	-----	Not required by contract
3. Canister changeout	7.9	-----	Not required by contract
***** SUBTOTAL *****	>5.0	>3.65	*****
NFBC Canister Preparation			
1. Transfer NFBCs (2) to Loader.	3.8	-----	Not required by contract

TABLE 6.0-3: SUMMARY OF TEST RESULTS VERSUS THROUGHPUT ANALYSIS

OPERATIONS	CALC. TIME MINUTES	MEAS. TIME MINUTES	COMMENTS
2. Load NFBCs into the canister.	3.4	-----	Not required by contract
3. Upend NFBC canister	1.1	-----	Not required by contract. This operation occurs every 2nd fuel processing operation.
4. Canister closure and changeout	12.2	-----	Not required by contract. This operation occurs every 2nd fuel process operation.
***** SUBTOTAL *****	20.5	-----	*****
TOTAL TIME TO PROCESS TWO PWR FUEL ASSEMBLIES	>260.0	>480.84	Total does not include the time for NFBC canister preparation.

7.0 RECOMMENDATIONS

7.1 INTRODUCTION

The very nature of a prototype project such as the Rod Consolidation System is one of building and testing what one considered to be the best design approach at the time the design effort was stopped and the fabrication effort commenced. Phase II was the design effort task and Phase III was the task to build and test the system. As a result of experience with the various facets of the Phase III effort such as purchasing components, fabricating components and structures, assembling fabricated and purchased parts, installing systems assembled by the fabricator and purchased engineered systems, and conducting the various types of tests, a number of problems were observed both with the systems and subsystems as designed and tested. Those problems that were encountered in the testing activities of the Phase III effort are discussed in Section 5.0 and have been detailed in each of the SOT and the IST Test Results and Analysis Reports which are presented as part of this volume. Other problems and associated recommendations are discussed in Section 3.0 of Volume II of the Phase III Final Report.

The recommendations were classified into two types:

1. Recommendations for design modifications and enhancements for the generic and production model, and
2. Recommendations for additional cold or hot cell testing.

7.2 RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS FOR THE GENERIC AND PRODUCTION MODELS

The recommendations for design modifications and enhancements have been detailed in each of the Test Results and Analysis Reports that were prepared for the individual SOTs and the IST. These reports are discussed in Section 4.0 and included as appendices to this volume. Table 7.2-1 provides a listing of the recommendations that have been made on the various systems that were tested.

In summary, a considerable number of design changes resulting in modifications to the existing system must be implemented before the system can be utilized to process actual spent nuclear fuel from commercial nuclear power plants. These modifications are necessary to achieve the design functional requirement to process 750 metric tons (MTHM) of heavy metal spent fuel per year based on a 60/40 split between PWR/BWR fuel types, and to permit remote control of necessary in-cell activities, to recover from off-normal events, and to perform in-cell maintenance and component changeout activities.

7.3 RECOMMENDATIONS FOR ADDITIONAL COLD OR HOT CELL TESTING

Cold cell testing activities in addition to those completed to date will be required before subsequent hot cell testing is performed. Furthermore, some additional suggestions for the hot cell testing have also been listed in Table 7.3-1 which should be implemented to prove the system for future processing of spent nuclear fuel on a production basis.

7.4 RECOMMENDATIONS FOR FUTURE PROTOTYPE DEVELOPMENT PROGRAMS

HALLIBURTON NUS's experience with the first three phases of the Rod Consolidation Project leads us to make the following recommendations regarding future prototype development activities that DOE may undertake:

1. Prototype development activities should not require the enforcement of NQA-1 quality assurance requirements until the basic design has been proven in cold testing.

Considerable time and money could have been saved in proving out the basic system design if the NQA-1 requirements had not been imposed on the project at the very beginning. It is only when the testing involves the actual handling of the special nuclear materials that the more stringent quality assurance programs need to be enforced.

2. Prototype development activities should be kept as simple as possible to prove basic design concepts before an extrapolation of the design is made to handle different variations on the basic design.

Considerable savings in time and money could have been realized if the Rod Consolidation Project had been restricted to proving out the ability to process one PWR type fuel assembly and one BWR type fuel assembly. The design requirements to handle so many different types of fuel assemblies in the Phase II and III efforts diluted the effectiveness of the engineering group in focusing on making sure the basic design was adequate to achieve the major functional requirements of achieving throughput and being able to perform in-cell maintenance and off-normal event recovery activities with provided remotely controlled service equipment.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

#	TEST #	SYSTEM	RECOMMENDATIONS
1/ 7	601 App.I 4.22	Process Control	<p>A facility should be provided for easy editing of "Cellstat.dat" in off-normal situations.</p> <p>More error reporting and better instructions on diagnosing fault conditions should be provided.</p> <p>Improve Control System response times.</p> <p>Replace proximity sensors with a more positive means of sensing end-of-travel limits.</p> <p>Replace load cells with a more positive means of sensing the presence of a fuel assembly.</p> <p>The supplier of the servo controllers should be reevaluated to obtain other types of controllers with improved performance.</p> <p>An alternative design should be considered for detecting end-of-travel limits.</p>
	215A App.I 4.23		<p>Increase Process Control System operating speed.</p> <p>Establish absolute position reference points.</p> <p>Eliminate the occurrence of two or more hold point or alarm point actuation for a single event.</p> <p>Evaluate preventive measures to inhibit the counting problem observed in IST testing.</p>

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

#	TEST #	SYSTEM	RECOMMENDATIONS
			Revise SINGLE mode operations to include all non-servo-motor operations as well as servo-motor operations.
			Operator Control Stations should be provided with larger desk areas.
			Evaluate the reset of rod count displays.
			Each display depicting fuel assembly, skeleton, or canister location should be provided with a physical reference such as north, south, east, or west.
			Update operating message logic so that the message is deleted or replaced after the completion of a task.
			Update operating messages related to task calls to other controllers to be specific for the task.
			Update operating messages to:
			1) delete wording which is appropriate to hold points of alarms,
			2) have the same nomenclature as displayed on the control screens,
			3) clearly specify which movement is occurring,
			4) specify the correct direction of motion, and
			5) utilize the standard format across all programmed operating modes.
			Add Accountability System transfer log reporting capability to record when each transfer occurred.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

#	TEST #	SYSTEM	RECOMMENDATIONS
			Add automatic Accountability System Status Report generation each time the supervision station is intentionally removed from service.
			Add on-line printout capability for the Supervisory Station.
			Provide editing capability for Clean Cell transfers.
2	6 0 0 App.I 4.21	CCTV and Audio Surveillance	Evaluate relocating the VCRs to a console situated between Operator Control Station 1 and 2.
			Evaluate the lens selection for the individual cameras.
	215A App.I 4.23		Provide alarm selection capability at the control console for alarm call camera functions for the situation when multiple alarms are presented at the same time.
			Provide end-of-tape alarm indications for the VCRs.
			Provide a setup CRT monitor for use in VCR setup and local playback.
			Relocate the Rod Extraction microphone away from the pull head drive noises.
3	213 App.I 4.15	R M - 1 0 A Manipulator (Robot Arms)	Testing of the RM-10A Manipulator per SOT 213 was deleted in the refocused test program. Furthermore, no testing related to the use of the special tools adapted for use with the RM-10A was performed.
4	212 App.I 4.14	Robotic Bridge Transporter (RBT)	Provide adjustment on end effector interface adaptor.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

#	TEST #	SYSTEM	RECOMMENDATIONS
			Increase DC motor size on end effector latching/unlatching mechanism.
			Reevaluate RBT festoon cabling system for both TAN and Generic facilities due to interferences with components on the North wall.
			Provide a chain tensioner on the telescoping tube's absolute resolver to minimize backlash of gears.
			Evaluate the possibility of increasing motor size for the telescoping tube drive.
	215A App.I 4.23		Revise positioning set points at the Clamping Table.
			Modify the design to prevent fuel assembly walking in multiple transfer operations or provide Control System recovery capability.
			Check RBT interlock adequacy with the Manipulator Transporter (MT) "SAFE" position for operation over the Staging Table.
			Add HAND mode FAHF clamp operating capability.
			Revise the load-rest logic for pick-up at the Fuel Assembly Storage Rack to test specifically at the position the fuel was lifted.
			Reevaluate the RBT load test logic.
5	214 App.I 4.16	Manipulator Transporter (MT)	Provide adjustment on the end effector interface adaptor.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
			Increase DC motor size on end effector latching/unlatching mechanism.
			Provide a chain tensioner on the telescoping tube's absolute resolver to minimize backlash of gears.
1	501 App.I 4.17	Fuel Assembly Storage Rack	Relocate load cell assembly toward center of rack.
			Provide greater clearance for fuel insertion into the rack.
2	203 App.I 4.3	Downender	Increase speed of movable frame and bottom support drives.
			Increase height of horizontal fuel supports.
			Provide each drive system with an absolute resolver for position control.
			Reevaluate the use of proximity sensors for end-of-travel limit switches.
			Decrease backlash on clamp drive system.
	215A App.I 4.23		Modify the operation of the Downender clamp so that it closes and opens to precise set points at all times.
			Minimize the travel required in the homing process for the bottom support.
			Evaluate the RBT position for HAND mode operations.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
3	209A App.I 4.10	Cutting and Staging Table	<p>Increase clamp lead screw length and modify clamp arms to enable a wider range of clamp travel.</p> <p>Increase clamp screw diameter.</p> <p>Increase Control System sample time or reduce motor speed to achieve more consistent clamp forces.</p> <p>Modify clamp pad supports to a roller surface to reduce clamp force necessary to center clamps.</p> <p>Spring load clamps to restrict clamp force to desired levels.</p>
	215A App.I 4.23		<p>Provide alignment indicator for the east end of the fuel assemblies for alignment verification.</p> <p>Revise fuel loading logic to load the last fuel assembly of the batch directly to the Cutting Table in all cases.</p>
4	209D App.I 4.11	Upper Cutting System	<p>Provide capabilities for remote tool changeout.</p> <p>Provide each drive system with an absolute resolver for position control.</p> <p>Reevaluate the use of proximity sensors for end-of-travel limit switches.</p> <p>Raise Z-axis to allow for spindle coupling engagement at a higher elevation.</p> <p>Reduce Upper End Fitting (UEF) clamp bottom surface to prevent UEFs from remaining balance within the clamp once the clamp is opened.</p>

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
			Provide a means to shield adjacent equipment from airborne abrasives and fines.
			Provide a larger cell to allow adequate spacing between equipment.
			Provide a means to cut out-of-square UEF skirts on B&W fuel assemblies without cutting fuel rods.
			Provide an improved means to remove the chips and turnings left in the guide tubes after the internal diameter tube cutting operations are completed.
	215A App.I 4.23		Modify the design of the Upper Cutting System end fitting clamp to get a positive grip on the end fitting.
			Eliminate the clamp, drill, and cutter alignment checks in the logic.
			Remove the cross-line generator intended for alignment verifications.
5	209C App.I 4.12	Lower Cutting System	Provide a positive drive system for the lower saw truck assembly.
			Provide each drive system with an absolute resolver for position control.
			Reevaluate the use of proximity sensors for end-of-travel limit switches.
			Replace the existing clamp system with a single drive, self centering clamp.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

#	TEST #	SYSTEM	RECOMMENDATIONS
6/ 7	208AB	W a s t e C o l l e c t i o n S y s t e m s	The systems operations testing of the Waste Collection Systems was eliminated in the refocused test program. No recommendations are offered at this time.
8	205 App.I 4.5	Fuel Assembly H a n d l i n g F i x t u r e (FAHF)	Provide a means to adjust the FAHF both level and parallel with interfacing equipment.
1	202 App.I 4.2	Fuel Assembly C l a m p i n g T a b l e	<p>Reevaluate the use of proximity sensors for end-of-travel limit switches.</p> <p>Evaluate the addition of reference points that can be used for remote homing of the Clamping Table elevation.</p> <p>Revise the HAND mode programming to go directly to the up set point after being at the last rod row.</p> <p>Rework the lower clamps to provide consistent closing force at the required set point.</p> <p>Provide a mechanical overtravel stop for the upper clamp swing bar.</p> <p>Reevaluate Clamping Table operating speeds.</p> <p>Increase the lower clamp opening capability to accommodate the effects of bowing in the fuel assemblies.</p> <p>Modify the Clamping Table elevation drive to avoid drifting down with the loss of power.</p> <p>Resolve level discrepancy between the north and south Clamping Table positions.</p>

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
			<p>Modify the design of the Clamping Table upper clamp slide such that Westinghouse assemblies are clamped at the upper or first grid.</p> <p>Evaluate the need to add a suitable end-of-travel limit switch for the Clamping Table upper and lower clamp slides for JOG mode operations.</p> <p>Evaluate CCTV camera coverage for Clamping Table elevation drive M-106I faults.</p> <p>Evaluate the impact of the "Extraction Complete" interlock requirement for opening the Clamping Table clamps if fuel is present on off-normal operations.</p> <p>Modify the lower clamps to firmly grasp the fuel assembly end fitting.</p> <p>Provide a rod slide to reduce the rod drop impact after extraction.</p> <p>Operate all clamps simultaneously.</p> <p>Modify the upper clamp insert to fit the upper grid more tightly.</p> <p>Adjust the load cell set point to sense the presence of skeletons only.</p> <p>Revise the clamp "CLOSE" indication set points.</p>
2	201 App.I 4.1	Rod Extraction	<p>Evaluate the pull head-extend gripper-open interlocks.</p> <p>Redesign the pull head proximity sensors so that full motor speed may be used in the JOG mode.</p>

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
			Redesign the pull head grippers so that the intended 160 to 200 pounds pulling force may be obtained when pulling different numbers of rods and for rod insertion lengths into the grippers of 0.5 inch to 2.0 inches.
			Evaluate the "CALL CAMERA" feature programmed for hold points.
			Evaluate the addition of protective covers at the east end of the Clamping Table to protect electrical components from the dropping fuel rods following extraction.
			Evaluate the rod drop distance after extraction in respect to irradiated fuel.
			Evaluate using a continuous flat surface for the removal of rods from the grippers.
			Evaluate using a flat surface for the support of dropped rods.
			Reevaluate the need for the pulling force data acquisition system.
			Reevaluate CCTV camera coverage for the rods-released hold point.
			Reevaluate the location of CCTV camera 7 to achieve a better view of the rod extraction at the first hold point.
			Reevaluate the location of CCTV camera 3 in respect to the safe position for the MT.
			Reevaluate the acquisition and presentation of torque information.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
			Reevaluate the acquisition and presentation of speed information.
			Revise the distance to the first hold point position to exceed the maximum tolerable rod growth.
			Increase the number of Extraction Table support rails to support rods at a minimum spacing of six inches.
			Increase the Rod Extraction pull head drive speeds.
			Increase gripper operating speeds.
			Provide CCTV coverage at the west end of the Rod Extraction Table to see rods being extracted and being side transferred.
			Relocate side transfer proximity sensor to provide unobstructed camera 8 coverage at the third extraction hold point.
			Increase the speed of the side transfer drive in retraction.
			Provide a very slow speed at the final extension to grip the rods.
			Provide CCTV camera coverage for the next rod row down.
			Revise the operating approach to provide visual monitoring of the extraction operation to the second hold point and increase camera coverage to permit viewing the full length of the rods on the Extraction Table.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
3	207	Rod Side	Provide each drive system with an absolute resolver for position control.
4	App.I	T r a n s f e r ,	
5	4.7	Compaction, and Loading	Reevaluate the use of proximity sensors for end-of-travel limit switches.
			Redesign the rod counters using a different approach.
			Replace the hopper bottom support with a roller assembly.
			Redesign the rake/consolidation table interface so that the rods do not slip under the rake.
			Redesign the pusher drive system to eliminate oscillations of the drive screw at high speeds.
215A			Reevaluate the application for counting the rods moved to compaction in side transfer.
App.I			
4.23			Increase the timing window for rod counting as rods are loaded to the slip sheet or increase the speed at which rods are loaded.
			Lengthen the side transfer to span the full length of the fuel rods being transferred and increase the number of side transfer fingers to push the rods at 18 inch centers.
			Increase the number of Compaction Table support rails to support rods at 6 inch centers to prevent rod sag and pinching at slip sheet loading.
			Lengthen the rake to span the full length of the fuel rods to prevent rod drag at the ends.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
			Increase the number of rake extensions to push the rods at 12 inch centers.
			Increase the depth of rake extensions to extend to the table surface but still clear the hopper frame.
			Revise the gate to provide overhead hold down coverage for the rods being loaded to the slip sheet.
			Revise the gate design to ensure positioning on the north side of the rods being loaded to the slip sheet.
			Add overhead hold down supports at the ends of the rods as they are compacted.
			Modify the rod loading counter to count accurately every time.
			Revise the hopper full set point to be two full fuel assemblies but provide the capability to load the canister with fewer rods than at set point.
			Increase the hopper row elevation incremental set point to add up to some free space for irregularities as the hopper is filled.
			Resolve logic problem related to the "CONSOLIDATE ALL RODS" hold point.
			Revise logic to enable auto sequence loading of the canister at the end of the batch.
			Provide better CCTV coverage for the "ENTER NUMBER OF RODS MOVED TO SLIP SHEET" hold point.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
1 4	206 App.I 4.6	Fuel Canister U p e n d e r , Grapple, and M e c h a n i c a l Closure	<p>Increase the width of the clamp opening from 9.0 inches to a minimum of 12.0 inches.</p> <p>Provide a generous (approx. 2.0 inches) tapered lead-in for each clamp arm.</p> <p>Provide each drive system with an absolute resolver for position control.</p> <p>Reevaluate the use of proximity sensors for end-of-travel limit switches.</p>
3	505 App.I 4.20	Fuel Canister Storage Rack	<p>Provide the overhead crane with a means of controlling the rotation of the canister.</p> <p>Provide a load indicator for remote applications to warn the operator of any abnormal weight conditions.</p> <p>Design the generic facility so that the fuel canisters do not need to be stored within the boundary of the fuel process cell.</p>
1	211 App.I 4.13	NFBC Loader	The SOT for the NFBC Loader was deleted in the refocused test program. The loader was utilized in the IST as a depository for the skeletons of the processed fuel assemblies.
	215A App.I 4.23		Modify the NFBC Loader north position to provide clearance for the FAHF.
2	204 App.I 4.4	NFBC Upender	Provide the main drive system with an absolute resolver for position control.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

#	TEST #	SYSTEM	RECOMMENDATIONS
			Reevaluate the use of proximity sensors for end-of-travel limit switches.
			Reevaluate the width of the clamp opening for the FBC canister.
			Provide tapered lead-ins on clamps for greater clearance to accept a canister during loading.
4	504 App.I 4.19	NFBC Canister Storage Rack	Provide the overhead crane with a means of controlling the rotation of the canister.
			Provide a load indicator for remote applications which will warn the operator when an abnormal weight condition is experienced.
			Design the generic facility so that the NFBC canisters do not need to be stored within the boundary of the fuel process cell.
1	208C App.I 4.9	Waste Container T r a n s f e r Fixture	The refocused test program deleted the performance of the SOT for the Waste Container Transfer Fixture.
2	503 App.I 4.18	O f f - N o r m a l Station	The process cell space envelope around the Off-Normal Station should be increased to facilitate movement of the RM-10A around the station.
			Evaluate design changes to the clamp assemblies to enable them to open wider.
			Evaluate design changes which provide better control of the clamping forces.
			Evaluate the need to provide torque indications on the control screen.

TABLE 7.2-1
RECOMMENDATIONS FOR DESIGN MODIFICATIONS AND ENHANCEMENTS

<u>#</u>	<u>TEST #</u>	<u>SYSTEM</u>	<u>RECOMMENDATIONS</u>
3	213 App.I 4.15	RM-10A End Effectors & Maintenance Tools	See WBS No. 1213
e	215A App.I 4.23	I n t e g r a t e d System	<p>Evaluate recovery for failure to remove end fitting from fuel assembly after tube cutting.</p> <p>Evaluate the possibility of loading fuel before all fuel canisters are loaded.</p> <p>Evaluate the CRT display of operating and response procedures on an operation-by-operation basis.</p> <p>Evaluate Process Control System recovery from an emergency stop action at any point in the processing activities.</p> <p>Evaluate the possibility of loading fuel before all fuel canisters are loaded.</p> <p>Space limitations make remote maintainability and off-normal recovery nearly impossible for some operations; therefore, an increased cell size should be evaluated.</p>

TABLE 7.3-1

RECOMMENDATIONS FOR PHASE IV TESTING

1. Perform all tests planned for Phase III that were not completed.
2. Perform construction completion checks such as wire checking, static alignments, etc., prior to initiating testing.
3. Perform component checkout operations to verify direction, position indications, range of travel, base travel speed, end-of-travel interlocks, interfacing system interlocks, alarm indications, and other component characteristics.
4. Repeat sections of SOTs to prove that all unmodified components are operable and that set points are correct. This should be done with partial fuel assemblies and components as appropriate.

Any mock-up fuel assembly component should be identical in size, weight, and other mechanical properties as the actual fuel. Off-normal components should be manufactured to reflect the range expected in the actual fuel.
5. Repperform performance sections of the SOTs for all modified components. This should be done with partial fuel assemblies and components as appropriate.
6. Repeat sections of the SOTs for HAND, SINGLE, and AUTO mode operations to confirm Control System processing operations, indications, and displays. AUTO mode testing should demonstrate the "HALT" function and should demonstrate recovery from an emergency stop at each step.
7. Perform SINGLE mode IST with mock-up fuel assemblies to verify that the sequence develops as expected, that all required operations are performed, that all indications are correct, and that all accountability updates occur correctly; to check all sequential steps of the Standard Operating Procedures; and to demonstrate process termination modes.
8. Perform AUTO mode IST with design batches of mock-up fuel assemblies for all fuel types to demonstrate performance times and process termination modes. Standard Operating Procedures should be validated in this phase.

TABLE 7.3-1

RECOMMENDATIONS FOR PHASE IV TESTING (continued)

9. Demonstrate off-normal recovery operations for design basis off-normal events and for testing off-normal developments. Validate related procedure sections.
10. Demonstrate maintenance operations for design basis and development maintenance activities. Validate related procedure sections.
11. Demonstrate housekeeping operations and validate related procedure sections. Demonstrate remote cleanup capabilities to capture accountable materials. Sources may be used to simulate fuel pellets in detection and recovery.
12. Perform dynamic function check to verify that all equipment is operable, adjusted, calibrated, tuned, etc. Demonstrate that all support equipment requirements are satisfied.
13. Perform HAND mode processing operations with hot fuel assemblies to demonstrate manual operating capability. The capability for manual operations should be proven first.
14. Perform AUTO mode processing operations with hot fuel assemblies to demonstrate normal operating capability.
15. Demonstrate whole batch operations with mock-up fuel assemblies that have been reconstituted to demonstrate system interactions from start to finish.
16. Demonstrate AUTO mode operations with a single fuel assembly on the Clamping Table.
17. Demonstrate normal operations with other fuel types, off-normal operations, and maintenance operations.
18. Demonstrate continued AUTO mode operations following recovery from defined off-normal events and applicable maintenance operations.

8.0 COMPLETED TEST DOCUMENTATION FOR TESTS PERFORMED IN PHASE III

8.1 PURPOSE

This section provides a guide to the location of the test documentation that was developed for Phase III testing.

8.2 PHASE III TEST PLAN

The Phase III Test Plan is discussed in Section 3 of this volume. A complete title is given in Reference 3-4.1. A copy of this document will be included in the QA/QC records that will be provided to DOE at the end of the Phase III effort.

8.3 COMPONENT CHECKOUT TESTS (FACTORY ACCEPTANCE TESTS)

The Factory Acceptance Tests (FATs) are discussed in Sections 3.1 and 4.1 of this volume. All documentation related to the FATs will be included in the QA/QC records that will be provided to DOE at the end of the Phase III effort.

8.4 SYSTEM OPERATIONS TESTS

The System Operations Tests (SOTs) are discussed in Section 3.2 and 4.2 of this volume. Copies of all Test Acceptance Criteria documents (TACs) will be included in the QA/QC records that will be provided to DOE at the end of the Phase III effort. Record copies of the SOT procedures that were completed by the Test Conductors are included as attachments to the Test Results and Analysis Reports for each SOT which are incorporated into Appendices I-4.1 through I-4.22 of this volume. In those instances where the performance of a SOT was deleted in the refocused test program, a clean copy of the latest revision of the test procedure is included as an attachment to the appropriate appendix.

8.5 INTEGRATED SYSTEMS TESTS

The Integrated Systems Tests (ISTs) are discussed in Sections 3.3 and 4.3 of this volume. Copies of all TACs will be included in the QA/QC records that will be provided to DOE at the end of the Phase III effort. This includes the TACs for the three tests that were not performed in the refocused test program as described in Section 3.3 of this volume. The record copy of the IST for normal processing of the Westinghouse 17x17 fuel assemblies is included as an Attachment to the Test Results and Analysis Report for that test which is incorporated into Appendix I-4.23. The latest version of the test procedures that were prepared for the three ISTs that were not performed, as discussed in Section 3.3 of this volume, will be included with the QA/QC records that will be provided to DOE at the

end of the Phase III effort. Copies of the applicable DOE comment letters on the latest versions of the TACs and Test Procedures of the ISTs that were not performed will be included with each test document.

8.6 SUMMARY

The record copies of the SOT and IST procedures which were completed during the Phase III test program are included as attachments to the Test Results and Analysis Reports. These documents are provided in Appendices I-4.1 through I-4.23 of this volume. Official record copies of SOT procedures which were not performed due to refocusing of the test program are also included as attachments to the appendices listed above. Copies of the completed FATs and uncompleted ISTs are included with the QA/QC records that will be provided to DOE with other deliverables at the end of the Phase III effort.

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