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VERIFICATION OF THE BARNWELL NUCLEAR FUEL PLANT (BNFP) MECHANICAL HEADEND DESIGN

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VERIFYING THE BNFP HEAD END DESIGN

VERIFICATION OF THE BARNWELL NUCLEAR FUEL PLANT

MECHANICAL HEAD END DESIGN

ABSTRACT

Design of the Barnwell Nuclear Fuel Plant mechanical head end includes unique provisions for remote maintenance, minimizes remote handling, and permits high throughput (6 MTU of spent fuel per day). Operability studies have been performed under a contract with the Department of Energy that: (1) assessed its capabilities for possible use in fuel encapsulation with or without compaction as a preparation for spent fuel storage, (2) verified the design of the mechanical head end as remotely maintainable, and (3) provided operator training.

INTRODUCTION

With the indefinite deferral of commercial reprocessing in the United States, various alternatives are being explored for storage or disposal of spent nuclear fuel. One possible alternative under review for the Department of Energy (DOE) at the BNFP would involve encapsulation of the spent fuel possibly preceded by compaction to reduce volume.

The BNFP head end includes a shielded, remotely operable and maintainable hot cell and several pieces of large, remote fuel handling equipment suitable for use in various spent fuel encapsulation and compaction schemes. In addition, with removal of the presently installed remote chemical processing equipment, sufficient space would be available for such additional equipment as might be required for compaction and encapsulation of spent fuel. Successful demonstration of the operation and remotability of the BNFP head end would verify its suitability as an in-place, tested, partially equipped facility that could be used for spent fuel encapsulation and compaction.

In the program carried out for the DOE, there were three interrelated major objectives: (1) to verify adaptability of the BNFP mechanical head end design for spent fuel encapsulation and compaction, (2) to demonstrate its remote maintainability, and (3) to provide operator training.

Testing and verification of equipment operability served to demonstrate, at least partially, its applicability in spent fuel encapsulation and compaction schemes. This testing and verification also demonstrated that the BNFP head end is remotely maintainable. All components were tested for remotability, modified as necessary, and retested. In addition, full remoting sequences were developed from preliminary concepts and demonstrated.

The operating personnel at BNFP have had extensive classroom training prior to and concurrent with their field assignments. This training included a review of the operational procedures for each piece of equipment. Verification work supplemented the classroom training and provided the "hands-on" feel of the equipment functioning.

DESIGN AND PROCESSING SEQUENCE DESCRIPTION

The unique design of the BNFP head end minimizes handling operations thereby permitting higher throughput. The fuel shear is designed to cut the entire fuel assembly, eliminating the need for removal of end fittings prior to shearing. Dedicated or single purpose equipment is designed to load fuel into the shear as opposed to crane or manipulator fuel loading. Removal of sheared fuel to different locations for various dissolution cycles is eliminated by the multicycle dissolvers. Dedicated equipment implements the scrap removal also.

Table 1 summarizes the function of the equipment in the Remote Process Cell (RPC). Figure 1 illustrates the general arrangement and location of this equipment. A description of the RPC as it was intended to operate as a part of a fuel reprocessing plant is as follows.

The fuel assembly is loaded vertically in the cart of the fuel transfer conveyor (FTC) within the fuel transfer pool (FTP). The fuel assembly is then transferred through a water seal to the RPC. The FTC delivers the fuel assembly to the RPC in a horizontal position. The assembly can be delivered "bottom end fitting first" to the shear or "top end fitting first". This feature provides flexibility for future fuel design.

The assembly is pushed laterally onto the table and then is pushed into the shear feed magazine by the transverse fuel pusher (TFP). The magazine cover is lowered pneumatically and the magazine drive advances the full fuel assembly, including end fittings, into the shear for cutting. The shear gags are movable plates for compacting (reducing voids) the fuel assembly and retaining it in position during cutting by the blade.

After chopping, the fuel pieces fall by gravity into the dissolver basket via a diverter chute which connects the shear to the dissolver barrel then operating on the dissolution cycle. The diverter forms a closed channel from the shear to the dissolver. The diverter is a rotating plug-type that can channel shear cuttings to four different dissolver positions.

Following completion of dissolution, leaching, and rinse cycles in the dissolver, a dissolver basket is lifted by the basket handling crane and grapple and transferred to the hull monitor. The fuel cladding which remains in the basket is referred to as hulls. In the hull monitor, the basket contents, or hulls, are scanned by a gamma detector for undissolved fuel. If the monitor indication meets acceptable limits, the hulls are sent to waste disposal via the dissolver basket dumper.

During normal operation, a dissolver basket handling crane and two maintenance cranes are available to the RPC for various operational requirements. In a remote maintenance situation during cell shutdown, a power manipulator can be moved into the RPC from the Crane Equipment and Maintenance Gallery (CEMG).

A wheel-mounted shielding door permits crane and power manipulator access to the RPC from the CEMG where this equipment is normally stored and maintained. The door opens by rolling horizontally on its embedded track into a recessed storage position between the two chemical cells which share a common wall with the CEMG and the RPC. Two pairs of crane rails lead from the CEMG into the RPC at different elevations with two crane bridges at each elevation. The portion of the crane rails in the vicinity of the door are hinged to permit rotation from their functional position so the shield door can be closed. The shield door provides adequate shielding for contact maintenance on items in the CEMG when it is closed.

A fuel transfer hatch is located in the same partition structure as is the dissolver basket dumper. This hatch permits the transfer of fuel assemblies or equipment into the RMSC where facilities are available for remote examination, remote maintenance, or decontamination. This is an alternate route to the CEMG floor plugs.

Table 2 summarizes the function of the equipment in the Remote Maintenance and Scrap Cell (RMSC). Figure 1 illustrates the general arrangement and location of this equipment. A description of the RMSC operation follows.

When the dissolver basket is ready for dumping, the basket is transferred by the basket handling crane from the hull monitor to the basket dumper. Before dumping a basket, a disposal container is positioned under the dumper chute in the RMSC by the hull transfer car. The dumper slowly inverts the basket and the hulls flow by gravity through the dumper chute into the hull disposal container.

The container is moved from under the dumper chute when it is filled. After its lid is secured, the container is decontaminated with water spray and positioned for loadout. All remote movement and positioning of the container is accomplished by the hull transfer car, which travels on a fixed, straight track running the length of the cell. The dumping station is located at one end of the cell, and the loadout station at the other.

After the hull disposal container is positioned for loadout beneath the ceiling hatch (in the RMSC ceiling), a shielding cask is placed above the shielding hatch. The hatch is opened, and the container is raised by the cask hoist into the shielding cask. The container is secured in the shielding cask and the hatch is closed. The cask is decontaminated, loaded on a truck by crane, and transferred to the solid waste storage site.

The RMSC is serviced by a crane and power manipulator.

The support equipment for the RPC and RMSC not previously mentioned include the following:

- Shielding windows to allow direct viewing of the majority of the operations
- Television, periscopes, and mirrors to supplement the windows for viewing the remote operations
- Adequate interior lighting of the cells to permit remote viewing of all operations

- Two master slave manipulator ports located at each shielding window

- Embedded service lines for water, steam, air, and decontamination solution located at each shielding window

- K-plugs (stepped wall plugs for providing additional electrical, fluid, or periscope service) located at each shielding window.

- A removable workbench located at the end window of the RMSC where small equipment is positioned for viewing and handling during remote maintenance.

The hatch between the CEMG and RMSC allows the RMSC crane and power manipulator to be brought to the CEMG for contact maintenance. Transfer of large pieces of equipment between the RPC and RMSC is also accomplished through this hatch.

DESIGN VERIFICATION

Summary

Based on the successful verification of the BNFP mechanical head end and an initial review of its equipment capabilities versus various spent fuel encapsulation and compaction requirements, the following conclusions were reached. The fuel transfer conveyor, transverse fuel pusher, and fuel transfer table, as constructed, could complement most, if not all, foreseen head end spent fuel encapsulation and compaction methods. The shear magazine, as is, and the shear with potential modifications could be used in some spent fuel methods. These methods would include those that involved a linear feed of the full fuel assembly and a full or partial chopping with or without subsequent compaction of cuttings. The diverter could most suitably be used in conjunction with the shear. Remote maintenance and scrap handling support equipment would be usable, as is. The dissolver, High Activity Waste (HAW) concentrator and hull monitor could be removed, since they are not required for encapsulation and compaction, and required encapsulation and compaction equipment installed in their place.

A full mechanical head end operability demonstration concluded the individual equipment testing. This demonstration verified that the mechanical head end could function as an integrated spent fuel handling system. A dummy fuel assembly, including end fittings, was processed from the loaded fuel transfer conveyor cart in the filled FTP. It was

transferred through the processing system, automatically sheared, and the cuttings remotely transferred to, and dumped by, the dissolver basket dumper into a hulls container in the RMSC. This demonstration was continuous and fully remoted. The operation was completely successful with all equipment functioning as per design.

Based on measured individual equipment rates, the mechanical fuel charging equipment, shear, and hull disposal path can function well in excess of design capacity.

A primary requirement factor in the design of a reprocessing facility is inclusion of the capability to maintain the equipment in proper working order. In the mechanical head end, the repair or replacement of in-cell equipment must be accomplished by in-cell maintenance equipment capable of these functions without "hands-on" intervention (i.e., remotely maintainable). These requirements would also apply to a dry Spent Fuel Encapsulation and Compaction Facility (SFECF). Remote maintainability was successfully demonstrated on the head end equipment as discussed below.

Fuel Transfer Conveyor

The fuel transfer conveyor system could be used "as-is" in a SFECF. Therefore, it was essential to demonstrate its remotability. The major challenge here was to remotely remove and replace the conveyor system's in-cell drive chain (30 meters, 700 kilograms) as well as its other in-cell components.

A drive chain remote replacement system was developed in preliminary testing and, after completion of fabrication and installation, was tested and verified to be operable. A chain basket that sits "piggyback" on the FTC cart is used in the RPC during the chain removal. The basket is used to gather and hold the chain. The basket is provided with a chain drive and an adjustable brake or clutch. Both drive motor and brake/clutch are controlled and powered via wiring which passes through a K-plug from the operating aisle. The motor minimizes side thrust on the chain handling crane by pulling the chain up and starting the chain feeding into the basket during removal. The crane ensures an even chain distribution in the basket. The adjustable brake or clutch provides tension on the chain as it is pulled back in with the conveyor drive sprocket during reinstallation.

All chain handling and basket positioning is performed with cranes. During chain remoting no power manipulator assistance is required.

The remote removal and reinstallation of the underwater and in-cell components of the conveyor system were verified. In the FTP, this verification included cart removal and replacement with the pool filled. In the RPC, the verification of remotability included the cart, its cover lift cams, the in-cell drive sprocket, the cart counterweights (start retract on horizontal rail in RPC until cart reaches vertical section where gravity takes over) and their support chain/rail system, and catch baskets.

It was also concluded that a multiposition remote television support frame would satisfy specific remote viewing angles required for fuel transfer conveyor counterweight remoting. The frame also provides increased flexibility for future viewing requirements. This frame is a "T" bar member that provides (via reorientation) 48 camera positioning points in a 13-by-13 foot area centered at the former single camera positioning point.

Shear

The shear magazine, as is, and the shear head with modifications could be used in some spent fuel handling methods; therefore, remotability was demonstrated on the full in-cell shear system and its spare components. This ensures that potential use of the system in a SFECF would not compromise the operability of the facility.

Replacement of shear in-cell components is required for failure, wear, or switching to different types of fuel assemblies. During shear testing, interchangeability testing of spare and different fuel-type components indicated various necessary remoting revisions.

Several shear head internal components were observed to be subject to the formation of adhesive films that interferred with remoting. To alleviate this problem, holes were drilled-and-tapped through the components to allow for a remotely installable jack screw that could break the adhesive film.

In various remoting applications on the shear for mechanical attaching and assembling, clearances of several thousandths of an inch had been used. Depending on application, clearances were increased to a minimum of 0.125 millimeters (0.005") up to approximately 0.250 millimeters (0.010") to ensure remotability.

Diverter

The diverter could find application in a SFECF to separate non-fuel components from the active fuel. Therefore, it required a remotability demonstration.

Since the fourth dissolver is not presently installed at the BNFP, the original welded seal plate at the fourth dissolver position of the diverter was removed and a remotable cover provided to permit access. Access provides four separate routes to channel material as might be required in a SFECF. Its positioning was successfully demonstrated remotely.

Dissolver and HAW Concentrator

The dissolver and HAW concentrator are chemical reprocessing equipment. Realistic SFECF schemes would not envision their use. However, prior to head end use as a SFECF which would contaminate the area, it was essential to demonstrate that the components of these systems could be replaced remotely.

Various equipment modifications were required to demonstrate successful dissolver remoting. The original design precluded remote viewing of dissolver barrel and wall support engagement during remote replacement Viewable lead-in guides were provided, and the dissolvers were successfully removed and replaced remotely. Lead-ins were also provided for each of the heat exchangers.

Reinforcing rings on the dissolver barrels were found to have unacceptably small tolerances to interferences during remoting. By rotating the rectangular cross section 90°, strength was preserved and interference clearances of several inches were developed.

All dissolver and HAW concentrator pipe jumpers were removed and inspected. The balance of the jumpers was inspected and corrected to ensure that lower termination would engage prior to upper termination which facilitates remoting. It is more difficult to seat two points simultaneously than to seat one and swing the other into alignment.

The rigidity of the jumpers was checked to see if excessive flexibility of the termination would so displace the end terminations that the displacement would interfere with alignment during replacement. On smaller lines, the rigidity generally had to be increased.

The response of the jumpers freely suspended to follow a rotating crane hook was checked. All jumper bails required hook guides that fitted the sides of the crane hook and greatly increased jumper response to hook rotation for remote positioning.

Support Equipment

BNFP head end remote maintenance and scrap handling support equipment could be used functionally in an SFECF, as is. Therefore, various modifications were made to enhance their remotability and operability. These modifications involved miscellaneous remoting devices, remote cranes, and cold side installation systems for in-cell equipment. After modification, remotability and operability were successfully demonstrated.

Handling frames, strongbacks or integral, single-point, lift bails were required to successfully remote various RPC and RMSC equipment. These permit "crane-only" remote transfers. Only handling frames required minor, if any, power manipulator assistance and this assistance is for engagement only. These approaches minimize reliance on power manipulators to either lift directly or secure wire rope slings between multiple equipment lift trunnions and a remote crane hook. Such manipulator use is difficult, time consuming, and increases the manipulator failure potential through excessive use. Also, in the RPC, three cranes are available to back up remote crane functions versus only one power manipulator.

A handling frame specifically designed for and tested at each of the three RPC shielding windows supplied with alpha seals (hot side removable glass plates that seal the window embedments to alpha contamination) permitted successful remoting of these seals.

A strongback was successfully demonstrated with the hull transfer cart in the RMSC that also removed the hull transfer cart cover and remoted the RMSC workbench. This multiple usage minimizes contaminated storage requirements.

The three handling frames for the internal components of the shear head were also provided with single point lift bails. These three were further modified for "crane-only" engagement and disengagement.

Since "crane-only" remoting does require a power rotatable hook, installation of remotely powered rotatable hooks on the two RPC cranes without them is now planned. This will ensure that "crane-only" remoting in the RPC is not interrupted by the failure of a single crane.

Modifications were made to preclude crane cables jumping their drum grooves, as occurs when remote lifts are made with loads that are not completely plumb or hook blocks are gounded resulting in slack crane cables. The system consists of a rolling follower that matches the drum groove and forces the cable to stay within the groove. It follows the cable across the drum as the cable is played out or taken in.

RPC crane loads placed beneath the RPC shelf hatches in the RMSC are not within the lateral limits of the RMSC crane hook. A remote equipment transfer truck was installed on the RMSC floor to permit transfers of these loads to the limits of the crane hook. Due to infrequent use and to minimize remote maintenance, the truck was designed without an integral drive. It is advanced or retracted by pull cables fed through floor eyes that the crane pulls up. The truck was successfully operated by crane as designed.

Facility design may require sloped floor conditions for drains in the cold operating aisles that support the in-cell work. These preclude the use of floor-mounted equipment installation vehicles that require level working surfaces. An alternative selected at the BNFP was overhead "I" beams to support monorail hoists for installation of equipment. The use of these I beams was successfully demonstrated for the installation of master slave manipulators and periscopes at the BNFP as well as for various elevated cold side drive units. It is also anticipated that this method, when used for removal, will facilitate bagging of removed equipment for contamination control.

TRAINING

Remote maintenance modification and demonstration of the head end equipment provided operator and maintenance training in full remote sequence development and implementation. Operability testing was also conducted to verify that the above equipment could support a SFECF to the degree that its original design intent permitted. This operability testing provided "hands-on" training for the operation personnel. Direct personnel involved included an engineer, a supervisor and four operators, and a supervisor and four mechanics.

CONCLUSIONS

Demonstration of remotability and operability at capacity verifies the BNFP design and its potential use for spent fuel encapsulation and compaction. It also provides a staff trained in remote operations and maintenance.

Demonstration of remotability indicated that the following items must be considered in the operation and maintenance of a remotely operated processing cell:

1. Full sequences must be implemented to ensure remotability.

2. Adequate viewing is essential.

3. Mechanical clearances must be adequate.

4. Rigidity must be sufficient for match point alignment.

5. "Crane-only" remoting alternatives should be considered prior to the use of wire rope slings for lifting.

6. Remote maintenance cranes are more versatile with powered rotatable crane hooks.

7. Remote cranes can eliminate in-cell drives on auxiliary equipment.

8. Cold side overhead "I" beam installation monorail hoists are an alternative to portable floor mounted installation devices for removable shielding wall equipment.

TABLE 1

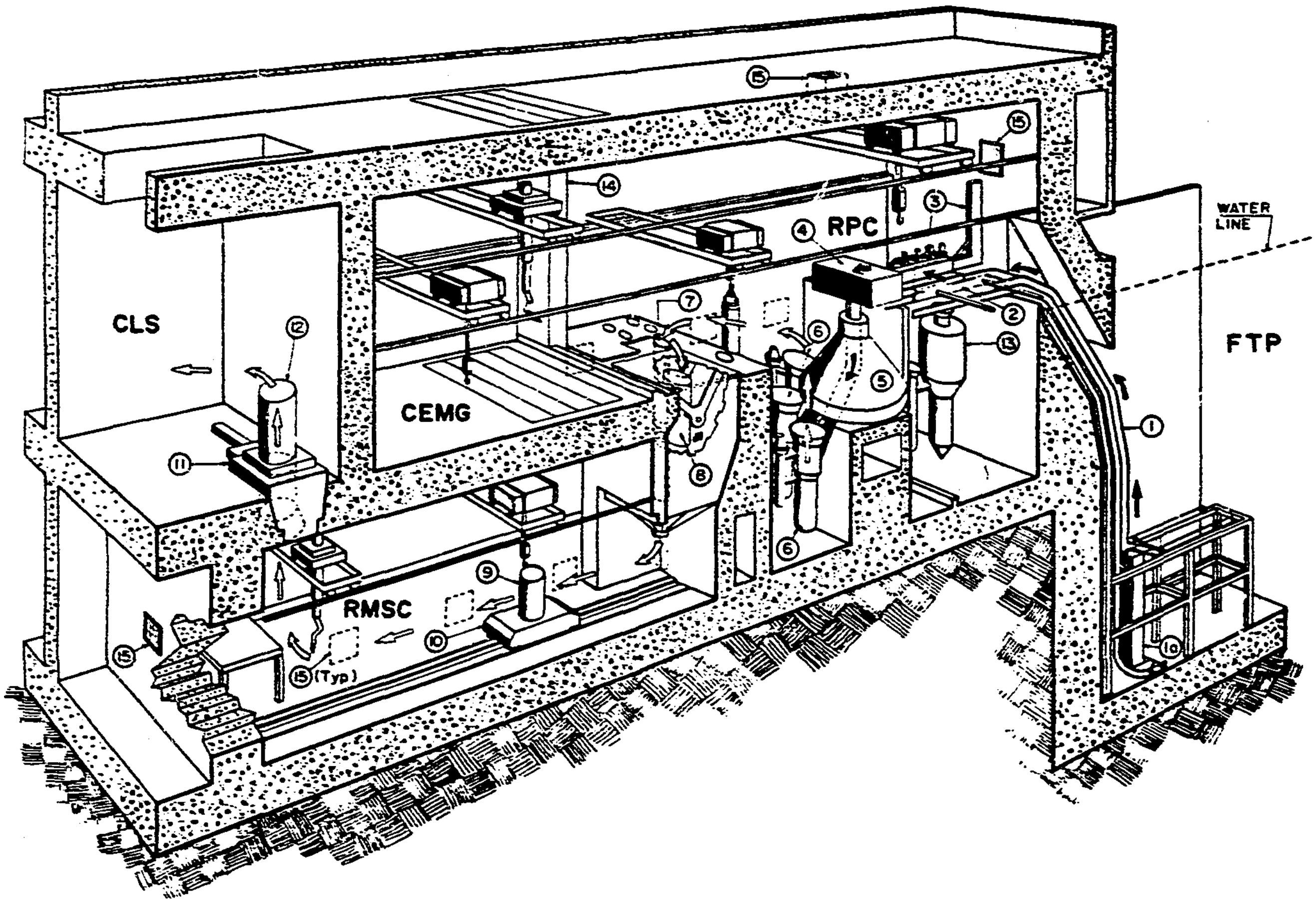
FUNCTION OF EQUIPMENT IN RPC

Equipment No.	Name	Function
1	Fuel Transfer Conveyor	Transports fuel assembly from the FTP to horizontal shear magazine loading position in the RPC.
2	Transverse Fuel Pusher	Provides means both to unload fuel assembly from conveyor and to load fuel assembly into shear feed magazine. The fuel transfer table between conveyor and shear feed magazine provides unloading position for fuel assembly delivered by fuel transfer conveyor.
3	Shear Feed Magazine	Properly positions fuel assembly for each cut and provides channeling for cutting dust and fines in conjunction with shear sweep-air system.
4	Shear	Cuts the fuel assembly which is held in position by its gags. Cutting performed by blade which executes a linear horizontal motion.
5	Diverter	Diverts sheared fuel from shear to any one of the three dissolvers.
6	Dissolver	Receives sheared fuel pieces and contacts them with poisoned nitric acid solution to dissolve fuel leaving only empty fuel rod pieces or hulls. Three unit barrel device.
7	Hull Monitor	Scans dissolver baskets to detect excessive undissolved fuel in hulls using gamma spectrometry.
8	Dissolver Basket Dumper	Dumps hulls from dissolver basket into hull disposal container.
13	HAW Concentrator	Concentrates fission product waste solution as a thermosyphon concentrator.
14	Shielding Door	Opens for crane access between RPC and CEMG and closes for shielding of RPC from contact maintenance work in CEMG.
15	Shielding Windows	Permits operator viewing of in-cell remote operations.

TABLE 2

FUNCTION OF EQUIPMENT IN RMSC

Equipment No.	Name	Function
9	Hull Disposal Container	Contains hulls for disposal. Stainless steel covered barrel.
10	Hull Transfer Car	Transports empty and full hull disposal containers in RMSC.
11	Ceiling Hatch	Permits transfer of hull disposal containers from RMSC to CLS.
12	Hulls Container Cask	Provides shielding for hulls containers during transfer from RMSC to waste storage area.



EQUIPMENT

1 FUEL TRANSFER CONVEYOR (CAR 1a)
2 TRANSFER FUEL PUSHER
3 SHEAR FEED MAGAZINE
4 SHEAR
5 DIVERTER
6 DISSOLVER
7 HULL MONITOR
8 DISSOLVER BASKET DUMPER
9 HULL DISPOSAL CONTAINER
10 HULL TRANSFER CAR
11 CEILING HATCH
12 HULL CONTAINER CASK
13 HAW CONCENTRATOR
14 SHIELDING DOOR (PARTIALLY CLOSED)
15 SHIELDING WINDOWS

PROCESS AREA

FTP — FUEL TRANSFER POOL
RPC — REMOTE PROCESS CELL
CEMG — CRANE EQUIPMENT & MAINTENANCE GALLERY
RMSC — REMOTE MAINTENANCE & SCRAP CELL
CLS — CASK LOADING STATION

LEGEND

← FUEL PATH
⇐ SCRAP OR HULLS PATH

BNFP MECHANICAL HEAD END

FIGURE 1