DRY ROD CONSOLIDATION TECHNOLOGY DEVELOPMENT

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ABSTRACT

The Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) is funding a program to consolidate commercial spent fuel for testing in dry storage casks and to develop technology that will be fed into other OCRWM programs, e.g., Prototypical Consolidation Demonstration Program (PCDP). The program is being conducted at the Idaho National Engineering Laboratory (INEL) by the INEL Operating Contractor EG&G Idaho, Inc. Hardware and software have been designed and fabricated for installation in a hot cell adjacent to the Test Area North (TAN) Hot Shop Facility. This equipment will be used to perform dry consolidation of commercial spent fuel from the Virginia Power (VP) Cooperative Agreement Spent Fuel Storage Cask (SFSC) Demonstration Program and assemblies that had previously been stored at the Engine Maintenance and Disassembly (EMAD) facility in Nevada. Consolidation will be accomplished by individual, horizontal rod pulling. A computerized semiautomatic control system with operator involvement will be utilized to conduct consolidation operations. During consolidation operations, data will be taken to characterize this technology. Still photo, video tape, and other documentation will be generated to make developed information available to interested parties. Cold checkout of the hardware and software was completed in September of 1986. Following installation in the hot cell, consolidation operations will begin in May 1987. Resulting consolidated fuel will be utilized in the VP Cooperative Agreement SFSC Program.

PROGRAM OBJECTIVES

The objectives of the Dry Rod Consolidation Technology (DRCT) Program are to demonstrate dry consolidation of PWR fuel assemblies and to develop and document technology associated with the dry consolidation process. Information gained during the consolidation process will be utilized by other OCRWM Programs such as PCDP, Monitored Retrievable Storage (MRS) and the Repository Programs. The consolidated fuel resulting from the Program will be utilized by the VP Cooperative Agreement Program to demonstrate long-term storage of consolidated fuel assemblies in steel storage casks.

FUEL SOURCES

Fuel to be consolidated will be taken from storage casks currently located at the INEL which contain spent fuel from VP as part of a SFSC Demonstration Program and Turkey Point fuel assemblies which were stored in air at the EMAD facility in Nevada and now reside in an inert gas lag storage facility at the INEL. The fuel has been selected to provide a uniform heat load totalling near the maximum heat rejection capacity of the consolidated fuel storage cask.

FUEL TRANSFER OPERATIONS

The casks containing the VP fuel to be consolidated will be transported into the TAN Hot Shop which contains the lag storage facility where the Turkey Point fuel is stored. This Hot Shop is located adjacent and is connected to the hot cell where the consolidation hardware will be operated. By use of remote operated cranes, fuel grapples, strongbacks, and a transport cart, the fuel will be removed from the storage locations and transported into the hot cell for consolidation. The strongback, shown in Fig. 1, consists of positions for two fuel assemblies and a consolidation canister. This complement of equipment is transported into the hot cell, consolidation is performed, and the canister

Fig. 1. Strongback.

containing the two consolidated fuel assemblies is transferred out of the hot cell into the Hot Shop for loading in the consolidated fuel storage cask. The cask loading is accomplished using the same remotely operated hardware described above. The process is then repeated.

FUEL ASSEMBLY PLACEMENT IN THE CONSOLIDATION MACHINE

The Docking System provides the interface between the Hot Shop fuel handling equipment and the hot cell consolidation hardware. The Docking System positions and holds the transport cart and strongback within the hot cell for all operations from the time the two fuel assemblies and their consolidation canister enter the cell until the consolidated fuel rods leave the cell in the canister.

Once the fuel assemblies and canister are positioned by the Docking System, the in-cell lifting fixture shown in Fig. 2 is used to remove the canister lid and place it in it's in-cell storage location; place the canister bottom in the fuel rod placement position; and locate a fuel assembly on the consolidation hardware.

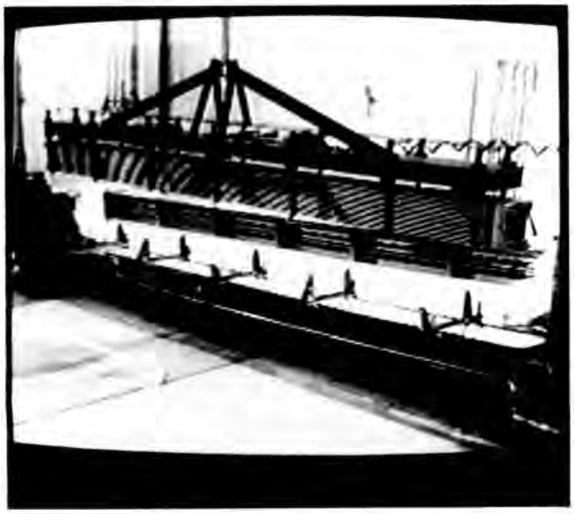

Fig. 2. In-Cell Lift Fixture.

END BOX REMOVAL

The first step in the consolidation process is to remove the fuel assembly upper end box. The end box removal assembly shown in Fig. 3 is used to accomplish this operation. The removal assembly is remotely positioned to hold the end box during orifice drilling and guide tube cutting operations. A drill fixture and drill bit are then remotely placed on the rod pulling head. The head is then automatically (computer controlled) positioned to drill the flow orifice out of the center guide tube. Drill feed rate and force are also automatically controlled by the computer. Drill rotational motion is provided by an air motor in the drill fixture. Upon completion of the drilling operation, the drill fixture is replaced with a guide tube cutting device shown in Fig. 4. The computer control system successively positions the cutter and cuts each of the guide tubes. As horizontal force is applied to drive the cutter into the guide tube, the cutter blades are forced out radially. An air motor provides rotation to the cutter. The combination of radial force and rotation accomplishes the guide tube cutting without the generation of machining chips. The guide tubes are cut above the first spacer grid. The end box removal fixture now pulls the end box and severed guide tubes horizontally away from the remainder of the fuel assembly. The horizontal movement of the end box is continued until the upper grid spacer clears the fuel rods. The end box removal fixture then rotates axially down and away from the fuel assembly position. In-cell manipulators are then utilized to place the end box, guide tube pieces, and upper grid spacer in NFBC storage.

Fig. 3. End Box Remover.

Fig. 4. Guide Tube Cutting Device and Flow Orifice Drill.

TABLE I (Con't)

Technology Data Collection Measurement Summary

Instrument or Sample		Measurement or Sample			
Type	Qty	Schedule	Qty	Description	Data Disposition
Gamma Scan	1	Turkey Point Fuel Assembly No. D01	1	The intact fuel assembly will be scanned using the existing Hot Shop equipment	The results will be documented and analyzed
		Surry Fuel Assembly No. R09	1	Same as above	Same as above
		Turkey Point Skeleton from D01 after consolidation	1	The assembly skeleton will be scanned	Same as above
		Turkey Point Skeleton from B02 after consolidation	1	Same as above	Same as above
		Surry Skeleton from R09 after consolidation	1	Same as above	Same as above
		Surry Skeleton from L04 after consolidation	1	Same as above	Same as above
Accumulated Dose (Film Dectector)	As Req'd	Continuous throughout consolidation	10	Film badge type detectors will be used to measure the accumulated dose. Detectors will be placed at selected equipment locations	Detectors will be removed and read when equipment failures occur or upon completion of consolidation

assembly identification. The video and photographic information will be correlated with the operations log and test engineer's written observations.

Rod Pulling Forces

Rod pulling forces are to be measured as the rods are pulled from the fuel assemblies. The measured forces are to include the initial breakaway and continuous sliding friction force (as a function of time/position) until the rod is free of the fuel assembly. The data are to be generated as a continuous analog signal proportional to the pulling force. Then the data are to be recorded in a format which will allow post test analog to digital processing for subsequent processing and analysis using a personal computer (PC).

Additional data are to be recorded in conjunction with the rod pulling force data. Data identifying the fuel assembly, the rod x and y location in the fuel assembly, and the rod pulled position (z axis) are to be recorded and correlated with the pulling force measurements. Where possible, rods with obvious defects (bowing, etc.) will be documented and correlated.

The pulling force and correlated x, y and z position data will be measured for all rod pulls. High and low data will be analyzed to correlate to fuel assembly burnup, enrichment, storage history, etc.

Rod Diameter

The spent fuel rod diameters are to be measured for the same rods for which the rod pulling forces are measured. However, since the rod diameter measurements will interfere with the normal consolidation process, it may be necessary to reduce the quantity of rods for which the diameters are measured. The diameter measurements will be made on two axes, 90 degrees apart, and will be continuous along the length of the rod after starting at a location six to eight inches from the top of the rod and ending six to eight inches from the bottom of the rod. The diameter measurement will be correlated to fuel assembly and rod position within the assembly as well as to the axial position along the rod. The data may be recorded in either an analog or digital format depending on which is more practical.

Curd and Zircaloy Collection and Characterization

A tray and vacuum system are incorporated into the consolidation equipment to capture crud during rod pulling. The smallest sample interval will be that for the consolidation of one fuel assembly. In addition to crud collection, zircaloy fines generated from cutting guide tubes and from rod pulling will be collected. The zircaloy fines and chips generated during the removal of the upper end box will be collected before the consolidation rod pulling process is started for that assembly. This will be performed to avoid, as much as possible, the mixture of

ROD PULLING AND PLACEMENT

Once the upper end box and spacer grids are removed, the assembly is ready for actual fuel rod pulling. The fuel rod gripper head shown in Fig. 5 is placed in the rod pulling assembly.

Fig. 5. Gripper Head.

The fuel rod pulling function is capable of fully automatic operation. Installed software operates x-y-z servo motors to position the gripper head, drive the puller assembly until the gripper head is engaged, and then actually pull the rod. The gripper head is positioned and driven until contact is made with the rod to be pulled. Contact actuates a switch which causes the gripper to close thus engaging the rod. Support of the pulled rod is provided by the sheet metal "fingers" shown in Fig. 6. Once the rod is fully withdrawn, the control system moves the fingers over a selected position in the canister. The fuel rod is then released. This process is repeated via a predetermined software program until all rods are pulled and placed in the canister.

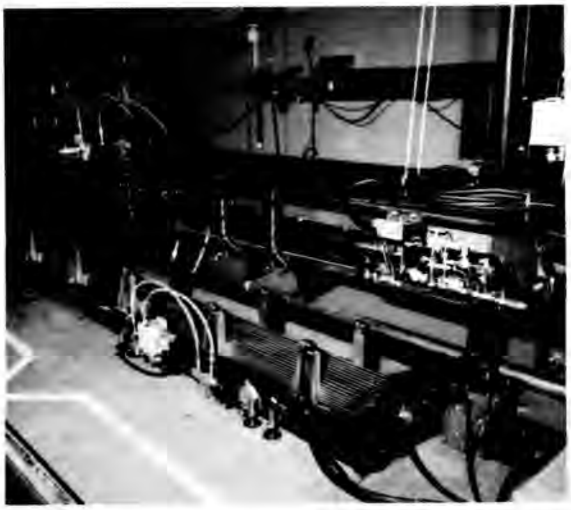

Fig. 6. Rod Positioning Fingers.

CONTROL SYSTEM DESIGN AND OPERATION

The control system is a computer based, software controlled, automatic system allowing manual operator intervention and control. The in-cell fuel and canister handling operations are accomplished via specially designed handling fixtures attached to and operated by existing hot cell manipulators, cranes, and associated control systems. Flow orifice drilling, guide tube cutting, and end box removal are automatic operations accomplished by the consolidation control system. Once the end box is removed, fuel rod pulling and placement in the consolidation canister can be accomplished fully automatically by the control system and software package. With the rods from two assemblies placed in a canister, canister closure, movement to the strongback and transporter, and movement out of the hot cell are again accomplished by use of specially designed handling equipment in conjunction with installed hot cell apparatus.

NON FUEL BEARING COMPONENT HANDLING

The upper end boxes and fuel assembly skeletons are manually removed from the hot cell and stored in a storage rack in the TAN hot cell water pit.

TECHNOLOGY DEVELOPMENT

The consolidation process will provide operational experience and the opportunity for collection of consolidation technology information to develop a data base for future planning and design of production scale fuel consolidation and non-fuel bearing component storage. During the consolidation process, measurements, observations, analysis, and photographic, video, and written documentation will be used to develop and disseminate technology associated with dry commercial spent fuel consolidation. Following is a description of these Technology Data Collection activities. A summary of data collection requirements is contained in Table I.

Fuel Rod Behavior

Visual observations of the fuel rods during removal from the fuel assembly and after they are removed will be documented using still color photography and color video equipment. Test Engineer and Operator observations will be documented using verbal and written descriptions. Features such as crud deposition, scratches, bowing and twisting, bending, discoloration, breakage, etc. will be recorded.

Still photography will be performed using a 35mm SLR camera positioned on a Kollmorgan periscope. Still photography will be limited to recording unusual fuel rod conditions and in a few instances the typical appearance of the fuel rods based on assembly position, burnup, and power history.

One color video camera will also be attached to Kollmorgan periscopes at the Filar eyepiece port. This video camera will be located at the end of the cell where the fuel rods are grasped with the consolidation equipment. Another camera will be placed inside the cell to allow close observation and viewing not obtainable with the Kollmorgan periscopes. U-matic recorders are to be used with the cameras for recording the video images. The 3/4-inch tapes will provide a high resolution. Voice recordings on the video tape will be used to document the process sequence and for specific rod and fuel

TABLE I

Technology Data Collection Measurement Summary

Instrument or Sample Type	Qty	Measurement or Sample Schedule	Qty	Description	Data Disposition
Rod Pull Force (load cell)	1	During processing of Turkey Point Fuel Assembly No. D01 (Hi-Burnup)	104 Rods	Breakaway and sliding friction force measured as the rod is pulled from the assembly; Accuracy=±2 lbs; Measured rods will be selected for location and symmetry	Data recorded for analysis
		During processing of Turkey Point Fuel Assembly No. D04 (Hi-Burnup)	104 Rods	Same as above	Same as above
		During processing of Turkey Point Fuel Assembly No. B02 (Lo-Burnup)	104 Rods	Same as above	Same as above
		During processing of Surry Fuel Assembly No. L04	104 Rods	Same as above	Same as above
		Surry No. N36	104 Rods	Same as above	Same as above
		Surry No. W09	104 Rods	Same as above	Same as above
Rod Pull Force (load cell)	1	Surry No. W52	104 Rods	Breakaway and sliding friction force measured as the rod is pulled from the assembly; Accuracy=±2 lbs; Measured rods will be selected for location and symmetry	Data recorded for analysis
		Surry No. R35	104 Rods	Same as above	Same as above
		Surry No. N36	104 Rods	Same as above	Same as above
Encoder (x and y axes)	2	Same as for rod pulling force measurements	832 Rods	The x and y position of the rod in the fuel assembly will be measured	Correlated with rod pulling force and diameter measurements
Encoder (z axis)	2	Same as for rod pulling force measurements	832 Rods	The z position of the rod as it is pulled will be measured	Same as above
Rod Diameter	2	Turkey Point fuel assembly No. D01	104 Rods	Rod diameter measured in two axes along the length of rod expect for approx. 8" at each end	Data recorded for analysis
		Turkey Point fuel assembly No. D04	104 Rods	Same as above	Same as above
		Turkey Point fuel assembly No. B02	104 Rods	Same as above	Same as above
		Surry fuel assembly No. L04	104 Rods	Same as above	Same as above
		Surry fuel assembly No. N36	104 Rods	Same as above	Same as above
		Surry fuel assembly No. W09	104 Rods	Same as above	Same as above

TABLE I (Con't.)

Technology Data Collection Measurement Summary

Instrument or Sample Type	Qty	Measurement or Sample Schedule	Qty	Description	Data Disposition
		Surry fuel assembly No. W52	104 Rods	Same as above	Same as above
		Surry fuel assembly No. R35	104 Rods	Same as above	Same as above
Vacuum and Filter	1	After end box removal for each fuel assembly	48	Zircaloy fines will be collected using the DRCT vacuum after guide tube cutting and end box removal	Filter with collected fines will be measured for weight and volume. The activity will be measured. The sample will be labeled and stored
		After consolidation for each fuel assembly	48	Crud will be collected using the DRCT vacuum after consolidation	Same as above
		Samples as directed by the test engineer	As Req'd	Crud samples will be taken from selected rods as directed	Same as above
Continuous air sample (pump with filter)	5	After every two fuel assemblies	120	Continuous flow with filters will collect airborne particulate during consolidation	The samples will be measured for size composition and activation
Stack monitoring equipment (existing)	1	Continuous	--	Stack gases are continuously monitored for radioactivity levels	Fission gas detection will be reported to Hot Cell operations. The data will be analyzed for content and quantity
Contamination Samples	As Req'd	After every two fuel assemblies (approx. 10 samples) or as directed by the test engineer	240	Surface swipes will be made to collect samples	Samples will be measured for activity, labeled, and stored for later analysis of content and particle size
35mm SLR Camera	1	As needed	--	A camera will be mounted on a Kollmorgan periscope camera port to take color photos of fuel rod conditions, etc.	Photographs will be documented by number and appropriately labeled
Video Camera (3/4-in. U-matic Video Recorders and Video Cameras)	2	As needed	--	Color video movies will be taken through a Kollmorgan eyepiece port to document process and conditions	Videos will be documented
Contamination Samples	As Req'd	For skeletons selected for gamma scan	20	Swipes taken to measure contamination of skeleton materials	Samples will be measured for activity, labeled, and stored for later analysis of content and particle size
Material Samples	As Req'd	Same as above	20	Swipes taken from skeleton materials for calibration of gamma scan	Samples will be labeled and sent to TRA for analysis

particles generated from cutting with those generated during the rod pulling process. Gross radiation level surveys, and volume and weight measurements will be performed for each sample.

Each filter for the vacuum will be weighed prior to its use to collect crud, etc. After crud collection, the filter and collected crud will be again weighed to detect the accumulated weight of crud and zircaloy fines to within plus or minus 0.1 grams. The filter and crud will then be placed in a counting chamber where the gross radioactivity levels can be measured. The samples will then be labeled and stored to be available for added scope characterization and analysis. In addition to collecting crud from each assembly of rods, crud samples from individual rods may be acquired as directed by the Test Engineer. Such collection would be performed on selected fuel rods depending upon the burnup, assembly condition, and power history. The extent that samples will be collected from individual rods will depend on the quantity of crud existing on the rods and operating budget limits.

Table I identifies the sequence and frequency for which crud collection will be performed.

Airborne Particulate

Five air sampling systems will be employed in the hot cell to measure particulate airborne radionuclide concentration at different locations and distances from the consolidation equipment. The sample devices will measure the airborne radioactivity in terms of activity per unit volume of air.

At the conclusion of the consolidation of each assembly, the sample device filters will be removed and the activity of the collected airborne particulate will be measured. The measured activities will then be correlated with the consolidation activities of each assembly. Samples will be labeled and stored. Pending availability of funding, the collected particles will be examined by a scanning electron microscope to determine the composition (by element) and particle size.

Fission Gas

Gross fission gas release will be measured when (if) rod cladding failures occur. Fission gas detection and measurement will be made using existing hot cell stack monitoring equipment. The fission gas detection equipment will be monitored. Any detection of fission gas released will be immediately reported to hot cell operations. This will allow identification of the most recently processed rods in order to retain their identification and canister location. This information will be useful should further analysis of the individual rods be required to evaluate the cause of the gas release. Measurement records from the existing detection equipment will be preserved and included with necessary documentation to correlate such data to the specific DRCT process and to the fuel assembly from which the fission gas was released.

Requirements for Fission Gas measurements are summarized in Table I.

DRCT Process Contamination Characterization

Radiation contamination samples will be periodically taken from selected incell and equipment locations to monitor contamination spread and increase during the consolidation process and during decontamination and equipment removal. The samples will be measured for gross radioactivity levels, labeled, and if needed, stored for later analysis.

Fuel Assembly and Skeleton Activation, Product Content, and Contamination Level Measurements

The objective of these measurements is to determine the quantity of activation products generated in a fuel assembly skeleton as a function of neutron irradiation and to determine the amount of surface contamination produced from rod consolidation.

Gross and isotopic gamma scans of intact fuel assemblies (one from Turkey Point and one from Surry) will be performed in the Hot Shop using the existing gamma scanning equipment before the fuel assemblies are placed in the hot cell for consolidation. The two intact fuel assemblies are to be gamma scanned as a function of axial position to obtain gross and isotopic activity profiles for the assembly. An ORIGEN-2 calculation will be used to calibrate these data to determine the absolute gross and isotopic activities in the assembly. After these two assemblies have been consolidated, the skeletons from the assemblies will again be gamma scanned to measure the total activation product content, isotopic identification and distribution as functions of axial position in curies/kg of skeleton material. An additional two skeletons will be gamma scanned to provide calibration data for all assemblies. These skeletons will be selected so that there are two skeletons from Turkey Point and two from Surry. Skeletons with high and low burnup histories from each plant will be analyzed. Small material samples (approximately 5 grams) must be obtained from the skeletons to allow calibration of the gamma scan data. Approximately four samples will be taken from selected components and locations. These will be analyzed by gamma spectroscopy. Swabs will be taken of several different locations on each assembly and measured to determine the contamination levels left on the skeleton after the fuel rods have been removed.

Hot Cell Ambient Temperature

A thermocouple type temperature measurement will be installed to measure the ambient in-cell temperature during the consolidation process. The temperature data may be useful for consideration during the evaluation and analysis of the consolidation process and for equipment failure cause identification. The temperature data will be recorded using the data acquisition and processing system. Date, time, and process status will be documented with the temperature data.

Evaluation of Radiation Effects

The accumulated radiation dose collected during the consolidation process will be measured at approximately ten selected locations associated with sensitive equipment hardware and electronics. Film badge type detectors will be used for such measurements. The detectors will be removed from the hot cell at the end of consolidation or earlier if equipment failures occur.

Removal and Decontamination

Equipment which has become contaminated and can be used for other projects will be swabbed to determine surface contamination. The equipment will then be decontaminated using standard procedures and the surface contamination measured and recorded. The equipment marked for disposal will be documented so that in the future, design requirements may be relaxed so that this type of equipment can be designed for inexpensive fabrication and disposal.

ANALYSIS AND DOCUMENTATION

All measured and recorded data will be evaluated and analyzed. A technical report will be issued to document the measured results, evaluations, and conclusions. Additional analysis and characterization of data samples as well as more extensive analysis and calculations to gain the maximum benefit and information from the TDC data may be performed if judged to justify associated costs.

ACKNOWLEDGEMENTS

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