SPENT FUEL STORAGE TECHNOLOGY DEMONSTRATIONS

AT THE IDAHO NATIONAL ENGINEERING LABORATORY (INEL)[a]

D. H. Schoonen and M. F. Jensen
Idaho National Engineering Laboratory
EG&G Idaho, Inc.
Idaho Falls, Idaho 83415

M. W. Fisher
Idaho National Engineering Laboratory
Department of Energy--Idaho Operations
Idaho Falls, Idaho 83402

ABSTRACT

Spent nuclear fuel research and development activities are conducted in accordance with Section 218 of the 1982 Nuclear Waste Policy Act (NWPA). Major objectives of Section 218 are to encourage and expedite the efficient use of existing storage facilities and the addition of new at-reactor storage capacity. Activities at the Idaho Engineering Laboratory (INEL) are pertinent to the following objectives:

- A cooperative demonstration program with the private sector to develop dry storage technologies that the Nuclear Regulatory Commission (NRC) can generically approve.
- A cost-shared dry storage research and development program at Federal facilities to collect the necessary licensing data.

These items are supported by tasks being performed at the INEL. Research and development programs include the testing of metal storage casks containing either consolidated or intact spent fuel in inert gas atmospheres. The casks, weighing nearly 90,718 kg (100 tons), are fabricated using nodular cast iron or forged carbon steel and contain basket assemblies which provide criticality control and spacing of fuel assemblies in individual cells. Small-scale rod consolidation systems are also being developed.

INTRODUCTION

The Spent Fuel Programs being performed and planned at the INEL for DOE are comprised of:

- Performance testing involving fuel storage casks with intact fuel or consolidated fuel
- Developing dry rod consolidation technology and prototypical equipment and testing of storage casks containing consolidated fuel rods in canisters
- Licensing and shipping of two loaded transportable/storage casks from West Valley, New York, to the INEL
- Developing a complement of NRC certified prototype casks for shipment of spent fuel from reactor facilities to future repository sites.

Cask performance testing in 1985 and 1986 for the Virginia Power (VP)/Department of Energy (DOE) project has provided engineering data supportive of the program objectives. The storage casks were tested while containing intact fuel in helium or nitrogen cover gases and in a vacuum. Cask performance and fuel temperature data were measured with the casks in the horizontal and vertical orientation. Cask performance and surveillance data will also be obtained during the Nuclear Fuel Services, Inc. (NFS) transportable/shipping cask project.

Dry, horizontal consolidation of spent fuel rods will occur in 1987 during the DOE sponsored small-scale rod consolidation activities. Storage cask testing with selected casks filled with consolidated rod canisters will be performed. Also, the follow on production-oriented prototypical rod consolidation project will provide additional technology development and rod consolidation process data.

The Test Area North (TAN) facility located at the INEL was determined to be the appropriate Federal facility in which to conduct these activities because of the availability of experienced staff, hot and cold test development areas, and the support needed to receive and store commercial spent fuel assemblies in support of these spent fuel storage programs.

These dry storage cask demonstrations support the DOE Office of Civilian Radioactive Waste Management (OCRWM) and NWPA objectives and will establish a data base which can be used for NRC licensing by generic rule of at-reactor dry storage cask installations. The latter will provide a significant expansion of at-reactor (on-site) spent fuel storage.

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Associated cask transportation experience includes the handling of large empty metal spent fuel storage casks received by railroad and the shipment of a large number of spent fuel assemblies in NRC certified shipping casks transported over the highways in transport vehicles having state issued special permits and meeting applicable Department of Transportation (DOT) requirements.

Storage Cask Performance Testing

The purpose of the VP/DOE storage cask performance testing at the INEL is to remove conservatism from the licensing of dry storage casks and provide a storage technology that is generically applicable so that the NRC can license dry storage of spent fuel by rule. The VP/DOE cask testing project is a cooperative effort involving Virginia Power, DOE, and EPRI. The cooperative agreement was established in 1984. The testing at the INEL will include casks containing both consolidated and intact fuel. The spent fuel assemblies are shipped from the Virginia Power Surry Power Station to the INEL using conventional licensed shipping methods. Decay heat generation rates for the selected fuel assemblies will total near the cask design limits. Thus, the casks may be tested above the NRC licensing limit. Data from the INEL testing will confirm storage cask performance, predictive modeling capabilities, and fuel integrity at prototypical storage conditions and will provide operational data to support the life cycle cost studies of dry fuel storage.

The technical objectives are developed by Pacific Northwest Laboratories (PNL), reviewed by the cooperative agreement participants and implemented by EG&G Idaho at the INEL.

INEL site preparations, fuel receipt, and the start of testing occurred in 1985. Storage cask testing with intact fuel was concluded in 1986 and cask testing with consolidated fuel will be completed in 1987/1988. Completion of testing reports and termination of the project is scheduled for mid-1989.

NFS Project

The Nuclear Fuel Services, Inc. (NFS) Spent Fuel Transportable Storage Cask Project will demonstrate the feasibility of packaging, transporting, and storing aged spent-fuel in two large dry storage casks. The Project will provide data for the railroad transportation of loaded, spent-fuel dry storage casks, utilizing NRC licensing for the one-time shipment of each cask. Applications for both casks have been submitted to the NRC with the licensing for the TN-BRP cask presently being processed by Transnuclear, Inc., the manufacturer of the casks. West Valley Nuclear Services (WVNS) and the WV Demonstration Project Office (WVDPO) will prepare the West Valley facility and supervise the fuel loading operations in the WV pool for this project. Demonstration of transportation and dry storage of spent nuclear fuel will involve the shipment of two casks loaded with fuel from West Valley, New York, to the INEL for cask testing and monitoring under storage conditions.

Arriving at the INEL, the NFS Project casks, TN-BRP and TN-REG, will be placed directly on the TAN storage cask test pad for long-term monitoring and surveillance. The project was initiated in early 1984 when DOE contracted with NFS for removal of the spent fuel from the West Valley pool. NFS in turn contracted with Transnuclear, Inc., for two large transportable storage casks, one to hold 85 boiling water reactor (BWR) assemblies stacked in two layers and one to hold 40 pressurized water reactor (PWR) assemblies. A summary of cask information is provided in Table I.

Prototypical Consolidation Demonstration Project

The Prototypical Consolidation Demonstration Project (PCDP) will demonstrate production scale spent fuel rod consolidation in a dry environment at the INEL TAN facility. The consolidation equipment developed during this project will provide the design basis for future equipment to be used at high-level waste repositories or the Monitored Retrievable Storage (MRS) facility. This project will expedite the engineering development and demonstration of prototypical dry rod consolidation equipment and associated handling equipment. It is being developed under a competitive design effort by the private sector and tested at the INEL using spent fuel assemblies acquired for the demonstration.

To obtain private-sector involvement, a single four-phased Request for Proposal (RFP) has been developed covering this project: (a) preliminary design competition, (b) detailed (final) design competition, (c) equipment fabrication, installation, and cold checkout, and (d) hot demonstration and qualification of equipment at the TAN facility. The hot demonstration will be performed at the INEL using

TABLE I

Information Summary for TN-BRP and TN-REG Casks

Features	TN-REG	TN-BRP
Fuel assembly capacity	40 PWR	85 BWR
Material	Forged steel	Forged steel
Nominal weight loaded	90,718 kg (100 tons)	90,718 kg (100 tons)
Nominal length	5.03 m (16.5 ft)	5.03 m (16.5 ft)
Nominal diameter	2.59 m (8.5 ft)	2.59 m (8.5 ft)
Maximum dose rate at 2 m	10 mR/h	10 mR/h
Heat load (total)	Less than 5 kW	Less than 5 kW
Cover gas	Nitrogen	Nitrogen

approximately 100 PWR and 100 BWR spent fuel assemblies typical of the light water reactor industry. The competitive design with private sector demonstration is to be completed by mid-1989. The selection and shipment of spent fuel assemblies and procurement and receipt of the casks which will later store the consolidated canisters are being evaluated.

CASK TESTING ACCOMPLISHMENTS AND STATUS

The progress of the three projects (VP/DOE Cask Testing, NFS Project, and PCDP) are discussed in reverse order in this section because most of the activity to date has been with the Cask Testing Project.

The RFP for the prototypical consolidation system was issued in January 1986. Appropriate evaluation criteria were established and the private sector competitive preliminary designs were completed in late 1986. Evaluation of the phase I preliminary design reports has also been completed. Preparation of Phase 2 final design proposals is currently in progress.

Progress in the NFS Project included completion of manufacturing the TN-BRP and TN-REG casks in 1985 and delivery of the casks to West Valley, New York. Processing of the applications for NRC licensing of the casks for one-time shipments are also in progress. Current plans are to load the fuel into the casks at West Valley while the licensing activities are in progress and make the shipments at a later date when the casks are approved.

VP/DOE storage cask testing and demonstrations are progressing on schedule. The INEL TAN facilities were modified to accommodate the remote transfer of spent fuel in TAN 607 Hot Shop from the shipping casks to the storage casks and to permit cask testing in the TAN 607 Warm Shop. In addition to the completion of all preparations for receiving and handling the casks and spent fuel, a concrete pad was constructed near the Hot Shop for temporary storage of loaded fuel casks. Storage will be in an open environment with appropriate monitoring and surveillance.

The GNS Castor V/21, the first storage cask, arrived at the INEL by rail in December 1984 and was moved by heavy haul transporter from the INEL railhead to the TAN facility in February 1985 and loaded with spent fuel in July and August 1985. The dual cask work stand in the TAN 607 Hot Shop is shown in Fig. 1. The first storage cask is shown in Fig. 2 during testing in the horizontal position in the TAN Warm Shop. Short-term monitoring and testing of this cask was completed in September 1985.

The GNS Castor V/21 is designed for a heat load of 21 kW and will hold 21 fuel assemblies. The cask was tested with a fuel loading providing a 28-kW heat

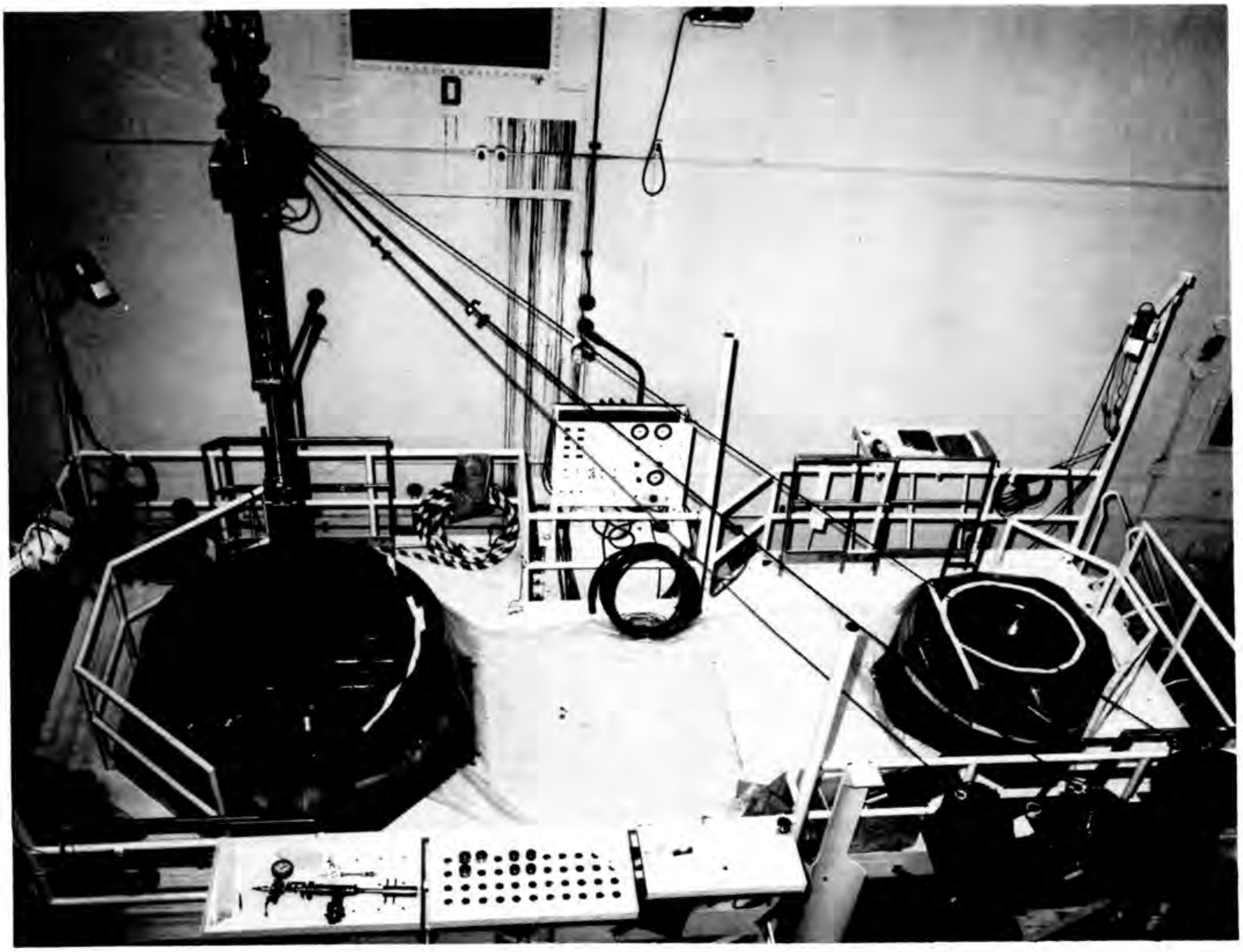

Fig. 1. Hot Shop Dual-Cask Workstand.

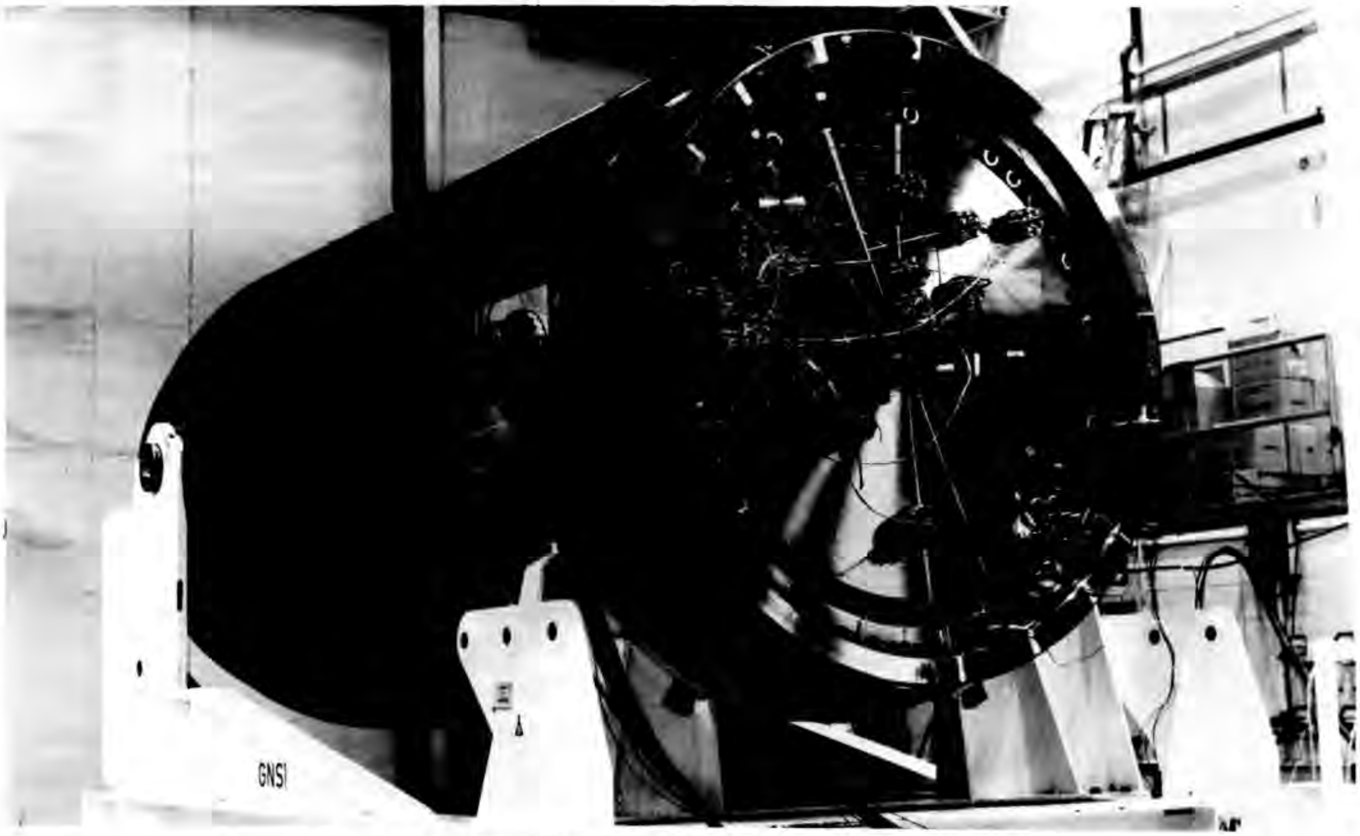

Fig. 2. Horizontal Testing of First Storage Cask (Castor V/21).

load. The cask can accommodate intact fuel assemblies or consolidated rod canisters.

The second cask, the Transnuclear, Inc., TN-24P, was received in October 1985, loaded in November through December 1985, and similarly tested with intact fuel. This cask will hold 24 fuel assemblies and can also accommodate consolidated rod canisters. The cask is designed to dissipate a 24-kW heat load under specific ambient and solar input conditions. The TN-24P cask (Fig. 3) was placed on the test pad in the spring of 1986.

The third storage cask, the Westinghouse MC-10, (Fig. 4) was received in mid-March 1986. This cask is designed for a heat load of 24 kW and will hold 24 fuel assemblies or consolidated rod canisters. Loading and testing of this cask was completed in June 1986.

The fourth storage cask for the VP/DOE cooperative agreement is being procured from Nuclear Assurance Corporation (NAC). This storage cask for consolidated fuel will be designated as the NAC S-100-C and will be supplied in early 1988. Dry storage cask features for the GNS Castor V/21; Transnuclear, Inc., TN-24P; Westinghouse MC-10; and NAC S-100-C storage casks are shown in Table II.

CASK HANDLING EXPERIENCE

Handling of the approximately 90,718-kg (100-ton) storage casks, as well as numerous spent fuel shipments, provided valuable cask handling experience at the INEL. Table III provides a tabulation of some of the more important items.

The precise alignment of shipping/storage cask lids and fixtures must be evaluated and the alignment and handling of the lid systems verified prior to in-air remote fuel transfer operations in the Hot Shop. Likewise the seal surface protectors which protect the cask sealing surfaces from marring or damage must be checked out prior to initiating remote fuel transfer activities.

High quality metal or elastomer gaskets are essential for repetitive use where incremental fuel loading or testing activities cause the lid to be removed and replaced several times. The metallic gasket on the GNS Castor V/21 primary lid was subjected to at least 12 such cycles of use and continues to function within the specified leak rate limits.

The cover gas system used to evacuate, backfill, monitor, and obtain gas samples should be carefully designed, fabricated, and tested. High quality fittings, quick disconnects, and valves should be utilized. A quick disconnect should not be utilized as the final barrier for air ingress, but should be backed by a block valve. The difficulty associated with backfilling the cask with a pure (>99%) cover gas and obtaining gas samples without introducing air should not be underestimated. Procedures should specify that the cask be pumped down and backfilled a minimum of two times to ensure purity (>99%) of the final cover gas.

The information required prior to handling a cask should include design drawings and specifications, operating and maintenance manuals, procedures, and spare parts. The dry run operational checkout of the cask and associated equipment should be performed for all phases, including handling, loading, and back-filling the cask with a cover gas and gas sampling.

Fig. 3. Second Storage Cask (Transnuclear TN-24P).

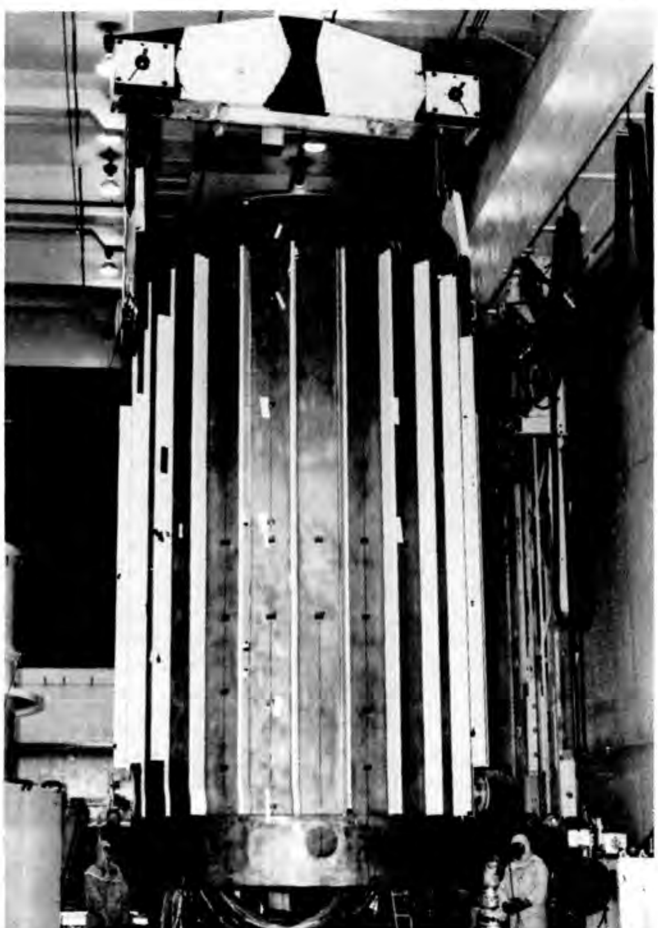

Fig. 4. Third storage cask (MC-10).

Cask vendor representatives should be in attendance and provide initial equipment training.

The preliminary training and operational checkout support provided by the cask vendors was very beneficial. Eighty-six fuel assemblies were transferred within the Hot Shop, and all cask handling activities were successfully performed. Storage cask testing has provided additional cask data and information as shown in Table IV.

The spent fuel cask testing and storage demonstrations at the INEL will enhance the overall dry storage technology data base. The initial results indicated that the shielding and thermal performance are good. Testing with the casks loaded with consolidated rod canisters will further support the verification of the computer codes used for thermal performance modeling.

VP/DOE CASK TESTING RESULTS

Where possible, testing of the VP/DOE storage casks is structured to test to the design limits of the cask. Thus, performance testing at the INEL may be in excess of the parameters identified for NRC licensing of a particular cask and may provide a basis for removing conservatism from the associated licensing process.

Each loaded storage cask was tested to verify thermal code predictions relative to cover gas or vacuum conditions within the cask, measuring both internal and external temperatures. This testing was performed for each cask with vacuum, helium, and nitrogen cover gases with the casks oriented in both the horizontal and vertical position. Other measured parameters are compared to shielding (dose rate) predictions. The containment specifications are also verified.

TABLE II

Dry Storage Cask Design Features

Design Features	GNS Castor V/21	Transnuclear TN-24P	Westinghouse MC-10	NAC S-100-C
1. Maximum weight on crane hook	104,326 kg (115 tons)	90,718 kg (100 tons)	90,718 kg (100 tons)	111,130 kg (122.5 tons)
2. Capacity	21 PWR	24 PWR	24 PWR	28 canisters
3. Proposed licensed heat generation capacity	21 kW	24 kW	24 kW	28 kW
4. Overall length	4.88 m (16 ft)	5.03 m (16.5 ft)	4.88 m (16 ft)	<4.88 m (<16 ft)
5. Outside diameter	2.44 m (8 ft)	2.44 m (8 ft)	2.44 m (8 ft)	<2.44 m (<8 ft)
6. Materials of construction	Nodular cast iron	Forged steel	Forged steel	Lead and steel
7. Neutron shielding	Polyethylene	Borated plastic	Borated plastic	Borated material

TABLE III

Cask Handling Experience

- Handling of Cask Lids
  - Lid Lift Fixtures - Alignment Guides
- Sealing Surface Protectors
  - Remote Installation
- Metal Gaskets for Lids
  - Repetitive Use
- Cover Gas System
  - Pressure Readout and Sampling
  - Vac-Vent-Fill
- Operational Tests
  - Functional Checkout - Technical and Operational Information
  - Cask Manufacturer Representative

In addition, limited fuel integrity examinations have been performed. This examination provides some data relative to fuel integrity, crud appearance/characteristics, and the typical phenomenon of elevation differences in fuel rods which occurs during reactor operation. Inspection of fuel rod growth in irradiated fuel assemblies provides evidence of random elevation differences of several rods in each inspected assembly (Fig. 5).

Temperature profiles and other data collected for the casks which have been tested support the code estimates and design predictions for the casks. The dose rate data and partial temperature data for the Castor V/21 storage cask test are shown in Figs. 6 and 7, respectively. Except for the dose rate spikes near the top and bottom of the cask, these data agree closely with the dose rate and temperature predictions.

TABLE IV

Dry Storage Monitoring Program Provides Cask Data

Cask Testing Elements

- Mechanical integrity of the cask
- Heat removal
- Radiation shielding
- Heat generation rate of the fuel
- Monitoring requirements
- Handling procedures
- Decontamination requirements
- Validate cover gas integrity
- Validation of thermal and shielding codes
- Consequences of system failures

The COBRA-SFS and HYDRA temperature code predictions used by PNL very closely agree with measured data. A comparison of the pretest predictions and measured values for the Transnuclear TN-24P storage cask are provided in Fig. 8. Dose rate measurements also are in good agreement with the cask manufacturers' predictions. PNL is analyzing the data for inclusion into the test reports for the three storage casks and the final program report. The cask test reports will be issued early in 1987.

Typical temperature and dose rate profiles for the storage casks are shown in Figs. 9 and 10.

The cask testing performance data has been used to support Virginia Power licensing activities as well as providing a basis for NRC licensing by rule of on-site dry storage cask installations. The data also provide an information base which will aid cask designers with design improvements, and permit evaluation and qualification of applicable computer

Fig. 5. Irradiated Fuel Rod Inspection.

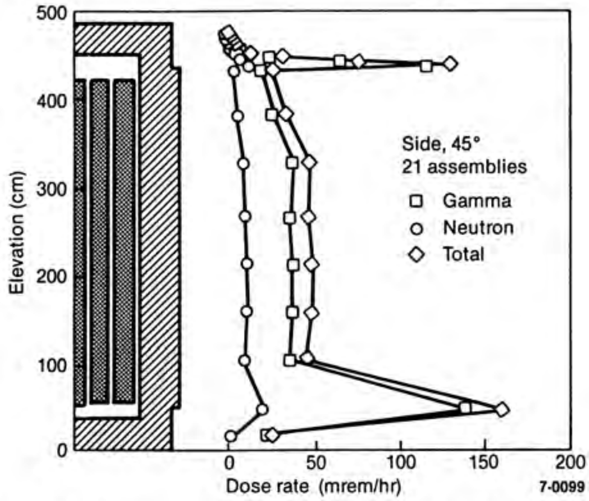

Fig. 6. Gamma and Neutron Dose Rates on the Side of the Castor V/21 Cask.

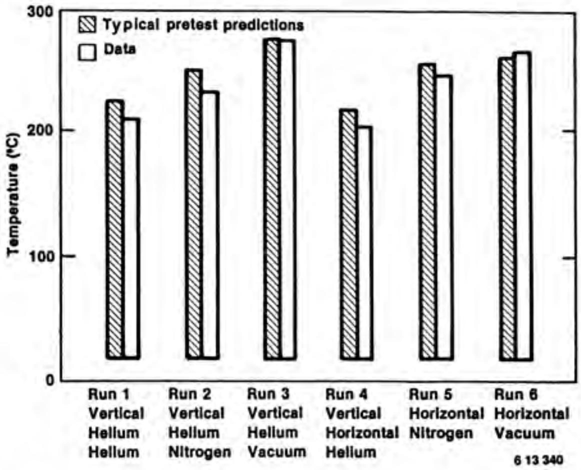

Fig. 8. Pretest Peak Temperature Predictions Compared to Test Data for Transnuclear TN-24P Cask.

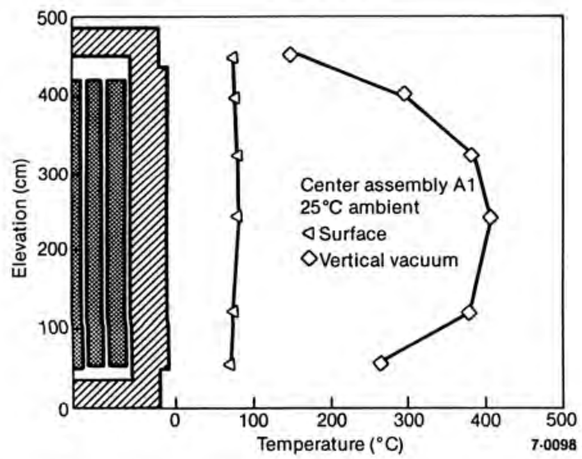

Fig. 7. Center Assembly Axial Temperature Profiles for the Castor V/21 Cask.

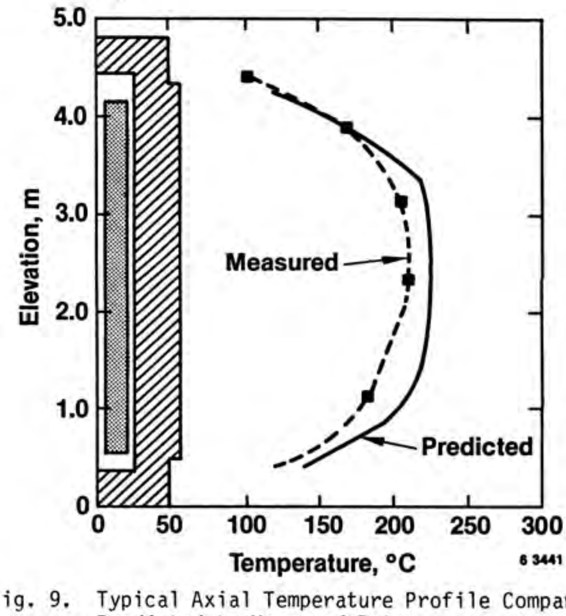

Fig. 9. Typical Axial Temperature Profile Comparing Predicted to Measured Data.

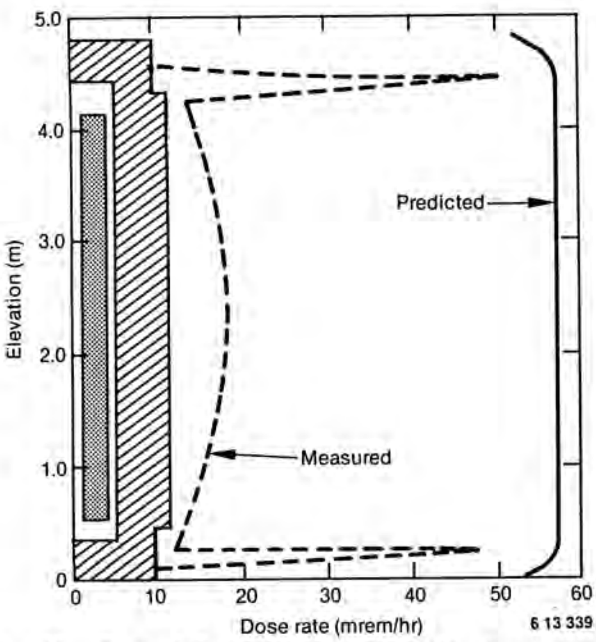

Fig. 10. Typical Total Dose Rate Profile Comparing Predicted to Measured Data.

codes. The dry storage cask installation at the Virginia Power Surry Station, already in progress, may be a forerunner of many such installations for the expansion of on-site storage capability by other utilities.

CONCLUSIONS

The spent fuel testing and storage demonstrations at the INEL will enhance the overall dry storage technology data base. The initial results from the cask testing indicate that the shielding and thermal performance of the casks are good. Cask performance testing with the casks loaded with consolidated rod canisters will further support the verification of the performance modeling. It is postulated that future cask designs will be able to use the code predictions with confidence.

Rod consolidation activities scheduled to be performed in 1987 at the INEL will add to the current dry cask storage technology data base. This testing will use the Transnuclear TN-24P storage cask that was previously tested with intact fuel.

The NFS Project transportation/storage cask activities will likewise add to the data base for NRC cask licensing information and railroad shipments. Storage cask monitoring and surveillance information will be obtained after the casks are placed on the INEL test pad.

The PCD Project will broaden the engineering information associated with production scale rod consolidation operations and provide valuable information/insight on design needs for future DOE installations.