POLICY ISSUE
NOTATION VOTE

July 27, 2004 SECY-04-0135

FOR: The Commissioners

FROM: Luis A. Reyes
Executive Director for Operations

SUBJECT: DEMONSTRATION TEST PLAN FOR FULL-SCALE SPENT NUCLEAR FUEL RAIL TRANSPORTATION CASK TESTING UNDER THE PACKAGE PERFORMANCE STUDY (WITS 200400069)

PURPOSE:

(1) To request the Commission's approval of the staff's proposed plan for a full-scale demonstration test of a spent nuclear fuel transportation cask and to describe the basis for the staff's recommendation.

(2) To inform the Commission of the staff's interactions with the U.S. Department of Energy (DOE) concerning potential funding for the Package Performance Study (PPS).

BACKGROUND:

Over the past 25 years, the staff of the U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Regulatory Research (RES), has conducted (or sponsored) and published a series of studies assessing the risks associated with transporting spent nuclear fuel. The latest of

CONTACT: Bret A. Tegeler, RES/DET/ERAB
(301) 415-6793

these studies, known as the Package Performance Study (or PPS), proposed a full-scale test to demonstrate the robustness of spent nuclear fuel transportation casks. This confirmatory research study is grounded in an enhanced public participatory process.

In February 2003, the staff published NUREG-1768, "Package Performance Study Test Protocols," which documented a proposed plan for performing extra-regulatory impact and fire tests (i.e., testing beyond the regulatory criteria) on certified rail and truck spent fuel transportation casks. Through extensive public meetings and comments, a wide range of stakeholders provided input for staff consideration of how the test should be conducted. On the basis of that input, the staff identified additional testing approaches and developed a Commission Paper (SECY-04-0029), dated February 23, 2004, which summarized the major public comment themes and presented testing options for the Commission's review and approval.

In response to SECY-04-0029, the Commission issued a Staff Requirements Memorandum (SRM), dated May 11, 2004, in which the Commission approved the testing of a full-scale, certified rail cask of a type that is currently being used, or is expected to be used in the foreseeable future to transport spent fuel. The Commission also directed the staff to commence procurement of such a cask and, prior to publishing a request for bids, inform the Commission of the specific details of the cask design and the related justification. The staff provided that information in a memorandum to the Chairman, dated July 2, 2004, requesting authorization to enter into a procurement exceeding $3 million.

Additionally, the SRM for SECY-04-0029 directed the staff to submit, for Commission approval, a plan for a demonstration test with sufficient instrumentation to collect data to confirm the validity of key analytical methods and assumptions, including scaling. In particular, the Commission specified that the demonstration test should be realistically conservative and should include exposure to a fully engulfing fire. The Commission further directed the staff to interact with DOE to determine whether the Department will provide funding for the demonstration test and to inform DOE that the PPS could be expanded in the future to include testing of a certified truck cask.

DISCUSSION:

The staff's process for developing a demonstration test plan involved (1) assessing statistics for rail transportation accidents involving both traditional commerce shipments and shipments of spent fuel transportation casks, (2) evaluating potential "realistic" accident scenarios to identify those that could result in a "realistically conservative" challenge to a spent fuel rail transportation cask, (3) developing a test plan that is consistent with the direction provided by the Commission, and (4) assessing the uncertainties in the test plan and the degree to which it would satisfy the Commission's direction.

Rail Transportation Accident Statistics

Over the past 25 years, NRC-certified packages have been used in 1,300 spent fuel shipments, and none of those shipments has challenged a rail transportation cask. Moreover, since 1970, there have been only four rail accidents involving trains transporting casks (only one of the four involved a train carrying loaded spent fuel casks), and none of those accidents directly involved the

rail casks. Consequently, the staff was not able to draw directly upon accident statistics to develop a "realistic" accident scenario that could result in a "realistically conservative" challenge to a spent fuel rail transportation cask.

The staff, therefore, also reviewed accident reports prepared by the Federal Railroad Administration (FRA), transportation studies conducted by Lawrence Livermore National Laboratory and Sandia National Laboratories, and research conducted by the Volpe Center of the U.S. Department of Transportation (DOT). Those resources support the conclusion that there is generally fewer than 1 rail accident per 10 million railcar-kilometers traveled.

These data indicate that train accident scenarios with the highest conditional probabilities, relative to other types of train accidents, are train derailments resulting in impacts or collisions with soil, roadbeds, rock, structures, railcars or locomotives, and/or vehicles at railroad crossings. Moreover, the great majority of these accidents would not be sufficiently severe to damage a cask. The staff, therefore, considered the following hypothetical cask and railcar accident derailment scenarios:

(1) cask and railcar impact with a rock outcrop
(2) cask and railcar impact with a tunnel entrance
(3) cask and railcar impact with a bridge abutment
(4) collision of a locomotive and a cask (attached to a railcar)

Potential Realistic Accident Scenarios

For train derailment scenarios involving impacts with rock outcrops, transportation studies indicate that only a small percentage of the ground adjacent to commercial railroad right-of-ways involves "hard rock." Depending on impact speed and cask mass, hard rock is the only impact surface capable of behaving like an unyielding surface. All other soil types would absorb significant energy before imparting energy to the cask. Thus, derailment scenarios involving rock surfaces are deemed to be of relatively low probability, and the more likely impacts with soil are judged to be unlikely to challenge cask integrity.

Derailment scenarios involving an impact of the cask and its conveyance (rail car) into a tunnel entrance or bridge abutment are more likely events. However, a unique set of circumstances would have to occur for the cask to directly impact either a tunnel entrance or bridge abutment. The staff, therefore, concluded that while these types of derailment scenarios are more likely than other scenarios, they do not represent a "realistically conservative" challenge to cask integrity (i.e., not much kinetic energy is transferred to the cask).

The staff then considered accident scenarios that involve a collision of a locomotive and a cask (attached to a railcar). This general class of accident is a more likely scenario in the relative ranking of these low-probability events, and the staff concluded that such a scenario could represent a "realistically conservative" challenge in that it would have the potential to impart enough energy into the cask to challenge cask integrity. In fact, the British used this accident scenario in "Operation Smash-Hit," the well-known demonstration test conducted by the United Kingdom's Central Electricity Generating Board (CEGB) in 1984. Specifically, this test involved

the high-speed impact of a locomotive into a rail cask attached to a rail car at approximately 160 kph (100 mph).

FRA accident reports indicate that locomotive impacts into railcars have occurred in the past. In particular, a 1995 accident that involved three trains (one of which was stopped and was impacted at low speed by a second train) resulted in a derailment of a railcar which overturned onto an adjacent track and was subsequently struck by a third train at relatively high speed. For these reasons, the staff chose to develop a test plan based on this accident scenario.

Demonstration Test Plan

The staff proposes to conduct a demonstration test involving the collision of a locomotive and a rail cask attached to a railcar. The proposed test scenario is based on the aforementioned 1995 rail accident, but adds a fully engulfing fire as directed by the Commission. The staff notes that the probability of occurrence of a real-world accident with a spent nuclear fuel cask similar to the proposed demonstration test scenario is small. NRC requires that spent fuel transportation casks be designed to survive a sequence of tests including a 30 foot drop onto an unyielding surface. This is a very severe test for spent fuel cask designs, and encompasses an extremely high fraction (well over 99%) of vehicle impacts at high speed. Only the most severe, incredible accidents might challenge a cask design, but their likelihood is so remote that the NRC considers the risk to public health acceptably low. The proposed demonstration test involves the following events:

1. A “typical” spent fuel transportation cask will be affixed to a rail car, and the cask-rail car assembly will be placed across railroad tracks to simulate a realistic derailment.

2. A locomotive with a realistic mass of trailing cars will impact the cask-car assembly at a “realistically conservative” speed. The 1995 accident that the staff has used as a basis involved an impact speed of approximately 80 kph (50 mph); however, the Commission’s direction suggested a speed of 120 kph (75 mph). The staff believes that further assessment is warranted to define an appropriate “realistically conservative” impact speed.

3. The cask, railcar, and locomotive will be fully instrumented with accelerometers, displacement transducers, strain gauges, thermocouples, and other similar devices to collect data for comparison with pre- and post-test analyses. Subsequent to the locomotive impact, the test progress will be halted so that the cask can be inspected to determine its post-impact condition.

4. Following the post-impact evaluation, a fire exposure test will be conducted. The staff considered two options for the fire exposure test. The first option is consistent with the Commission’s direction to include exposure to a “fully engulfing” fire. The second option would involve a more realistic scenario, but would be significantly more difficult to define and conduct.

(a) This option would include a fully engulfing fire exposure test, in which the cask would be removed from the "flat" car and placed on a test stand in a fire test pit. This test would be consistent with a fully engulfing, optically dense hydrocarbon fire of a 30-minute duration, as specified in Title 10, Section 71.73, of the *Code of Federal Regulations* (10 CFR 71.73)

(b) The second option for conducting a fire exposure test would involve constructing a "pit" around and under the cask-car assembly at its post-impact location. The car-cask assembly would be exposed to a hydrocarbon fire that surrounds the assembly in a realistic setting, for a duration of least 30 minutes. (The staff has not yet fully developed the specifics of this scenario.) The "realism" underlying this option is that hydrocarbon fuel from the locomotive or another tanker car could leak into a "gouged" trench in the ground or a natural low spot in the terrain, and then ignite and burn for an unspecified period of time. However, the cask would be shielded by the tracks and the flat car, resulting in a less severe fire exposure than in option 4a. Additionally, the test conditions and boundary conditions would be extremely difficult to characterize or control and, therefore, would result in a fire exposure test of a severity that cannot reasonably be predicted or controlled; it could only be measured and assessed after the test.

The staff's recommendation is to conduct the fully engulfing fire exposure test defined in option 4a, because this option is consistent with the Commission's direction and constitutes a "conservative" post-impact fire exposure test with well-controlled conditions.

Uncertainties in the Test Plan

The test proposed by the staff will demonstrate the robustness of a certified spent fuel transportation cask in the event of an accident (which is very unlikely and severe) involving a fully engulfing fire. However, by virtue of being "realistic," the test is more complex than the relatively straightforward testing used in the certification process defined by 10 CFR 71.73. This complexity introduces a number of uncertainties, stemming largely from the anticipated nonlinear nature of the collision between the locomotive and the cask-car assembly. Additionally, the staff has not yet finalized certain aspects of the test design(impact speed and orientation of the cask-car assembly relative to the tracks, for example) that could have a significant effect on the test and its challenge to cask integrity.

The associated analysis predictions and testing conditions also introduce uncertainties into the demonstration test. Analysis predictions strongly depend upon the accurate representation of material properties and structural details of the cask, rail car, and locomotive. Because such details may be difficult to obtain, the staff will rely on engineering judgment and approximations to compensate for the anticipated lack of detailed design drawings. These uncertainties and reliance on engineering judgment and approximations will increase the error bounds in predicting the test results, and will increase the uncertainty in key parameters to be measured during the test, thereby requiring an increase in the measurement range for those parameters.

In the SRM for SECY-04-0029, the Commission directed the staff to design a demonstration test with "sufficient instrumentation to collect data which confirms the validity of appropriate key analytical

methods and assumptions, including scaling methodology, that serve as the basis for NRC regulations and regulatory review of transportation cask applications." The Commission's direction to confirm the validity of the scaling methodology will not be achievable in the context of traditional engineering analysis validation from the demonstration impact test. In this traditional context, validation of the scaling methodology would involve comparing analysis results with the results of two or more well-defined experiments. These validation experiments require well-controlled boundary conditions in order to limit uncertainties in interpreting test data regarding component response. The boundary conditions for the demonstration impact test are complex and not well-controlled for several reasons, including the uncertain behavior of the crushing of the locomotive and railcar, uncontrollable friction effects between the cask, rail car, and the ground, as well as the failure strength of the cask tie-downs.

What the Demonstration Test Can Accomplish

A full-scale demonstration test that is sufficiently instrumented can provide a clear demonstration of cask robustness under realistic accident conditions, data that can be used in assessing the ability of current analysis techniques to predict cask response under complex impact conditions, and data that can be used to assess thermal analysis methods applicable to the fully engulfing fire test.

Full-scale impact and fire demonstration tests on spent nuclear fuel rail transportation casks have not been conducted in the past 20 years. Past rail cask demonstration tests have involved lighter, lower capacity designs, which would not likely be used in the foreseeable future to transport spent fuel. Conducting a full-scale, realistically conservative test can demonstrate the robustness of a cask design that is likely to be used in shipments of spent fuel. The proposed demonstration impact test will provide this demonstration. The proposed fully engulfing fire test will demonstrate the integrity of the full-scale rail cask in a severe thermal event.

The instrumentation that is expected to be used in the proposed test (consisting of accelerometers, displacement transducers, thermocouples, and strain gauges, combined with a state-of-the-art data acquisition system) will provide data not available from prior tests. The specific types of instruments, their locations on the test cask, rail car, and locomotive, and the anticipated ranges of parameters to be measured will be determined through pre-test predictions of the impact and fire tests. An initial assessment of the instrumentation package and ranges of parameters will be provided to the Commission six months after the Commission approves the test plan. The staff expects that the details of the instrumentation package will evolve somewhat as more detailed pre-test analyses are completed, and any significant evolution in the instrumentation package will be reported to the Commission.

Earlier methods for analyzing cask response in full-scale demonstration tests involved lumped parameter mathematical models, two-dimensional (2D) finite element analysis, and coarse three-dimensional (3D) finite element analysis. For the proposed tests, the staff plans to use modern analysis techniques, such as those used in the current cask certification process. These modern analysis techniques take advantage of more efficient, state-of-the-art, computing capabilities and the development of high-fidelity 3D finite element models. These models allow for more accurate representation of cask structural details and material characteristics involved in a realistic accident scenario that is indeed three-dimensional.

In addition, the staff expects to develop a collaborative analysis effort (e.g., round-robin participation) with domestic and international stakeholders who are expected to use a wide variety of analytical tools and modeling techniques. By performing both pre- and post-test analyses, the collaborative analysis effort is expected to yield insights into the most accurate modeling techniques for both the impact and fire tests. Prior experience with such collaboration has shown that all of the participants gain valuable experience and insights into conducting analyses of complex structure and loading conditions.

DOE Interaction

The staff is continuing to interact with DOE to determine whether the Department will provide funding for the PPS demonstration test. On June 10, 2004, the staff met with representatives from the DOE Office of National Transportation to discuss the potential use of truck casks in PPS testing. DOE is currently evaluating the potential use of truck casks and will keep us apprised. The staff is also exploring the possibility of DOE contributing funding for the purchase of a rail cask.

RESOURCES:

Resources necessary to support the Package Performance Study are currently being addressed and will be finalized once the Commission renders its decision on the proposed test plan.

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objections. The Office of the Chief Financial Officer has also reviewed this paper for resource implications and has no objections.

RECOMMENDATION:

The staff recommends that the Commission should approve the proposed PPS demonstration test plan. Upon receipt of the Commission's approval, the staff will develop comprehensive test metrics and commence analysis predictions of key cask performance measurements for estimating instrumentation gauge range and later comparison with test data. The staff will continue to interact with DOE regarding the contribution of funds for the PPS and the future use of truck casks for transporting spent fuel.

/RA Martin J. Virgilio Acting For/

Luis A. Reyes
Executive Director
for Operations

In addition, the staff expects to develop a collaborative analysis effort (e.g., round-robin participation) with domestic and international stakeholders who are expected to use a wide variety of analytical tools and modeling techniques. By performing both pre- and post-test analyses, the collaborative analysis effort is expected to yield insights into the most accurate modeling techniques for both the impact and fire tests. Prior experience with such collaboration has shown that all of the participants gain valuable experience and insights into conducting analyses of complex structure and loading conditions.

DOE Interaction

The staff is continuing to interact with DOE to determine whether the Department will provide funding for the PPS demonstration test. On June 10, 2004, the staff met with representatives from the DOE Office of National Transportation to discuss the potential use of truck casks in PPS testing. DOE is currently evaluating the potential use of truck casks and will keep us apprised. The staff is also exploring the possibility of DOE contributing funding for the purchase of a rail cask.

RESOURCES:

Resources necessary to support the Package Performance Study are currently being addressed and will be finalized once the Commission renders its decision on the proposed test plan.

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objections. The Office of the Chief Financial Officer has also reviewed this paper for resource implications and has no objections.

RECOMMENDATION:

The staff recommends that the Commission should approve the proposed PPS demonstration test plan. Upon receipt of the Commission's approval, the staff will develop comprehensive test metrics and commence analysis predictions of key cask performance measurements for estimating instrumentation gauge range and later comparison with test data. The staff will continue to interact with DOE regarding the contribution of funds for the PPS and the future use of truck casks for transporting spent fuel.

/RA Martin J. Virgilio Acting For/

Luis A. Reyes
Executive Director
for Operations

DISTRIBUTION: Andrew Murphy, RES, Amy Snyder, NMSS, Robert Lewis, NMSS, Larry Camper, NMSS, Margaret Federline, NMSS, Robin Baum, OGC
DET r/f and MEB r/f **RES 2004199; WITS 200400069**
DOCUMENT NAME: C:\ORPCheckout\FileNET\ML042030156.wpd
OAR in ADAMS? (Y or N) **yes** ADAMS ACCESSION NO: ML042030156 TEMPLATE NO:SECY- 004
Publicly Available? (Y or N) yes DATE OF RELEASE TO PUBLIC **10 days after dispatch** SENSITIVE? No
To receive a copy of this document, indicate in the box: "C" = Copy without attachment/enclosure"**E**" = Copy with attachment/enclosure"**N**" = No copy

*SEE PREVIOUS CONCURRENCE

OFFICE	Tech. Editor	N	ERAB/DET		ERAB/DET		DET	
NAME	P. Garrity		B. Tegeler*		M. Evans*		M. Mayfield*	
DATE	7/22/04		7/21/04		7/22 /04		7/22/04	

OFFICE	NMSS		NMSS		OGC		OCFO	
NAME	W. Brach*		J. Strosnider*		K. Cyr*		J. Funches*	
DATE	7/23/04		7/23/04		7/21/04		7/23/04	

OFFICE	RES		DEDMRS		EDO			
NAME	C. Paperiello*		M. Virgilio		L. Reyes			
DATE	7/23/04		7/ 27 /04		7/ 27 /04			

OFFICIAL RECORD COPY