POLICY ISSUE
INFORMATION

January 6, 2003 SECY-03-0002

FOR: The Commissioners

FROM: William D. Travers
Executive Director for Operations

SUBJECT: EVALUATION OF THE EFFECTS OF THE BALTIMORE TUNNEL FIRE ON RAIL TRANSPORTATION OF SPENT NUCLEAR FUEL

PURPOSE:

To inform the Commission of the staff's evaluation of a hypothetical event involving a spent fuel transportation cask subjected to the fire environment that occurred during the Howard Street tunnel accident in Baltimore, Maryland, in July 2001. This paper responds to the Staff Requirements Memorandum associated with COMJSM-01-0002, "Transportation of Spent Fuel."

SUMMARY:

This paper details the staff's actions related to the investigation and analysis of the Baltimore tunnel fire event that occurred in the Howard Street tunnel on July 18, 2001. The staff was tasked with assessing the consequences of this event on the transportation of spent nuclear fuel. This paper describes the following elements of the staff's actions for this investigation: the staff's coordination with the National Transportation Safety Board (NTSB) to determine the details of the train derailment and fire, the staff's technical analysis of the event, completed with assistance from the National Institute of Standards and Technology (NIST), the Center for Nuclear Waste Regulatory Analysis (CNWRA), and Pacific Northwest National Laboratory (PNNL), and the results of the staff's efforts. The staff has concluded that for a 10 CFR Part 71 approved spent fuel transportation cask subjected to the Howard Street tunnel fire, no release of radioactive materials would have resulted from this postulated event, and the health and safety of the public would have been maintained.

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BACKGROUND:

After the July 18, 2001, derailment of a CSX freight train inside the Howard Street tunnel in Baltimore, Maryland, the Commission directed the staff to investigate the incident and determine if current regulations for shipping spent nuclear fuel by rail are adequate to withstand the thermal conditions (i.e., flame temperature, fire duration, presence of flammable and other hazardous cargo) experienced in the tunnel. In coordination with the NTSB, and with technical assistance from NIST and the CNWRA, the staff identified the thermal conditions that were present in the tunnel during the accident.

It should be noted that although the U.S. Department of Transportation (DOT) and the U.S. Nuclear Regulatory Commission (NRC) do not have regulations requiring dedicated trains to transport spent nuclear fuel (i.e., trains shipping only spent nuclear fuel), the Association of American Railroads (AAR) has developed a performance standard for the transportation of spent nuclear fuel by rail. This performance standard dictates the use of railcars that have been analyzed and tested to minimize the possibility of derailment. Standard tanker cars used to ship flammable or hazardous materials would not meet this performance standard. Therefore, if this performance standard is followed, carriers would not ship hazardous materials on the same train as commercial spent nuclear fuel. To date, the practice in the industry has been to make spent fuel rail shipments by dedicated trains, and the industry has been self-regulating in this respect.

DISCUSSION:

The accident in the Baltimore tunnel involved a CSX freight train traveling through downtown Baltimore, Maryland. The NTSB presented details of the accident to NRC.

The Howard Street tunnel is a single-track rail tunnel, 2.7 kilometer (1.7 miles) in length, with an approximate 0.8% upward grade in the direction the train was traveling. The tunnel is constructed mostly of concrete and refractory brick. The tunnel has vertical walls and a circular ceiling and measures approximately 6.7 meters (22-feet-high) by 8.2 meters (27-feet-wide). The dimensions vary slightly along the length of the tunnel.

The CSX freight train consisted of three locomotives and 60 cars. As the train traveled through the tunnel, 11 of the 60 cars derailed. The cause of the derailment remains under investigation. A tanker railcar transporting approximately 108,263 liters (28,600 gallons) of liquid tripropylene was ruptured in the derailment and subsequently caught fire. Liquid tripropylene carries a National Fire Protection Association hazards rating of three, for flammability. This rating is the same for gasoline and signifies that tripropylene can be ignited at ambient conditions.

The freight train was also transporting tanker cars full of hydrochloric acid and other hazardous materials, which were not thought to have contributed to the fire. The precise duration of the fire is unknown.

Temperatures in the tunnel during the fire were reported (in the local media) to be as high as 815°C (1,500°F). There were indications that portions of the tunnel may have reached this temperature; however, the actual time/temperature history of the fire is not known, but has been estimated through the NIST Howard Street tunnel fire model, as described below.

ANALYSES:

The staff's consequence assessments are described in the following four sections:
1. "Event Identification"
2. "Determination of Temperatures Generated in the Howard Street Tunnel (NIST)"
3 "Confirmation of Temperatures Experienced by Materials from the Tunnel (CNWRA)"
4. "Final Staff Evaluation and Analysis of Spent Fuel Transportation Cask"

Event Identification:

The CSX train derailment accident and subsequent fire were widely reported in the media. However, detailed information was scarce. To obtain the detailed information required for the staff's analysis, on September 13, 2001, the staff met with the NTSB experts investigating this event to obtain data required for its assessments. The NTSB provided factual and photographic information of the event known at that time, such as: mechanical damage to railcars done by the derailment; fire damage to railcars; fire damage to the tunnel; and preliminary assessments of the thermal conditions in the tunnel during the fire. During the staff's meeting with the NTSB, the staff was informed that the NTSB would analyze the temperatures reached within the tunnel. However, such analyses would take time to develop. Consequently, as an interim assessment, the staff performed a scoping analysis to assess the consequences from a postulated tunnel fire event on a spent fuel transportation cask. The results of the scoping analysis were reported previously (Reference 1) and will not be discussed further.

Determination of Temperatures Generated in the Howard Street Tunnel (NIST):

Subsequent to the staff's scoping analysis, the NTSB informed the staff that it would not provide a detailed thermal analysis of the tunnel accident, as initially anticipated. The NTSB stated that since the fire was not the cause of the derailment, but a consequence of the derailment, its investigation would not quantify the temperatures reached inside the tunnel. To quantify the temperatures that existed within the tunnel, NRC contracted with NIST fire modeling experts to perform such an assessment. The results of the NIST analysis are summarized below.

Using a state-of-the-art analytic fire model, NIST calculated fire temperatures as high as 1000°C (1800°F) in the narrow flaming region of the fire. The hot gas layer above the railcars, within three rail car lengths of the fire, averaged 500°C (900°F). The tunnel surface wall temperature reached 800°C (1500°F) where the fire directly impinged on the top of the tunnel. The average tunnel ceiling temperature, within a distance of three rail cars from the fire, was 400°C (750°F).

To obtain confidence in the results calculated by NIST, the analytic models were validated against data taken from a series of fire experiments conducted in an abandoned West Virginia highway tunnel. The data were part of the Memorial Tunnel Fire Ventilation Test Program performed by the Federal Highway Administration and Parsons Brinckerhoff, Inc.

The internal NIST report documenting the fire analysis is provided as Attachment 1 to this paper. This report will be issued as NUREG/CR-6793 upon completion of printing.

Confirmation of Temperatures Experienced by Materials from the Tunnel (CNWRA):

As an added validation of the fire analyses performed by NIST experts, the staff contracted with CNWRA experts in fire testing, fire modeling, and materials analysis, to examine the physical properties of the paint and metals from the rail cars (box cars and tanker cars) removed from the tunnel after the fire. To determine the time and temperature exposure of these samples, metallurgical analyses were performed on several different materials, including sections of the boxcars exposed to the most severe portion of the fire, as well as an air brake valve from the tripropylene tanker car. The CNWRA analyses confirmed the temperatures calculated by NIST as consistent with the conditions observed in the paint and metals. The CNWRA report on its analysis is provided as Attachment 2 to this paper.

Final Staff Evaluation and Analysis of Spent Fuel Transportation Cask:

The NRC staff, with the assistance of thermal analysis experts at PNNL, developed a refined 2-dimensional finite element analysis thermal model of the transportation cask, including the transport cradle. The purpose of the refined model was to perform a more realistic thermal assessment that captured the non-uniform temperature distributions which existed in the Howard Street tunnel fire. The staff imposed both temperature and flow boundary conditions derived by NIST for the Howard Street tunnel fire to the spent fuel cask analytic model. The staff examined two scenarios in the cask thermal response analysis.

The first scenario was based on the DOT regulations that require railcars carrying radioactive materials be separated by at least one railcar (known as a buffer car) from hazardous materials or flammable liquids. The staff's analysis assumed one railcar [20 meters (65.6 feet)] separation between the spent fuel cask and the fire source. The staff applied a boundary condition, based on the NIST analysis, onto the cask in three "zones." The upper third of the cask was conservatively exposed to the maximum temperatures and flow that existed in the upper portion of the tunnel; the middle third of the cask was conservatively exposed to the maximum temperatures and flow that existed along the side of the tunnel; and the bottom third of the cask, including the shipping cradle, was conservatively exposed to the maximum temperature and flow conditions along the lower elevations of the tunnel. The cask model accounts for the effects of radiation from the tunnel walls and the effects of the mounting cradle which secures the transportation cask to a specially designed railcar.

The second scenario placed the cask 5 meters (16.4 feet) from the fire source. This scenario was considered a bounding scenario, since it is unlikely that a spent fuel transportation cask, if one had been involved in the Howard Street tunnel derailment and fire, would have been adjacent to the fuel source.

Both scenarios were calculated through 150 hours of fire exposure (i.e., the fire was assumed to burn at the maximum temperatures calculated for the 150 hour duration). Note that the liquid tripropylene fuel burned for about 3 hours in the actual Howard Street tunnel fire, and the tripropylene tank car held enough fuel for a burn time of 6 to 7 hours based on a 9 meter pool diameter.

For the 20-meter (65.62-feet) scenario, the analysis indicated that the short-term temperature limit of the Zircalloy fuel cladding, 570°C (1058°F), would have been exceeded 116 hours into the fire exposure. For the 5-meter (16.4-feet) scenario, the fuel cladding temperature limit would have been exceeded at 37 hours into the fire exposure. The short-term temperature limit is a conservative regulatory tool used to ensure no fuel rod cladding breach. It is not a temperature limit that implies gross rupture of fuel cladding. Additional calculations were performed to determine stresses that resulted from the fire in the welded multipurpose canister (MPC) that provides the primary boundary to release of radioactive materials. The stress calculations indicated that the MPC would not fail during the fire, and thus there would be no radioactive release for the analyzed event.

The staff also examined the risk of radioactive doses to first responders after a severe fire accident. Since the cask's polymeric neutron shield would be damaged under severe fire conditions, the magnitude of the neutron field would increase in the vicinity of the cask. This assessment is accounted for in staff's review of the HOLTEC HI-STAR cask application under 10 CFR 71.73, where the neutron shield was assumed to be consumed during the hypothetical accident condition fire. The licensing analyses for this cask demonstrated that without the neutron shield, the post-accident dose rates would be within the limits prescribed in 10 CFR 71.51. Therefore, the complete loss of the neutron shield does not pose a risk to the health of the public outside of those allowed by NRC regulations.

CONCLUSION:

The staff's assessment of the hypothetical event of a spent nuclear fuel transportation cask in the Howard Street tunnel fire environment identified no public health and safety concerns. The staff's analyses indicated no failure of the structural components of the transport cask nor failure of the canister containing the spent fuel inside the transportation cask. The refined cask analysis described above confirmed the existence of significant conservatism in the staff's preliminary scoping analysis. Consequently, the staff concluded that there would be no release of radioactive materials from this postulated event and that existing programs provide reasonable assurance of adequate protection to the public.

REFERENCES:

1. "An Analysis of a Spent Fuel Transportation Cask Under Severe Fire Accident Conditions." Chris Bajwa. ASME pressure Vessel and Piping Conference Proceedings. August, 2002. (ADAMS Accession #ML021690392)

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Attachments: 1. Internal NIST Report
2. CNWRA Report

the fire exposure. For the 5-meter (16.4-feet) (buffer car) scenario, the fuel cladding temperature limit would have been exceeded at 37 hours into the fire exposure. The short-term temperature limit is a conservative regulatory tool used to ensure no fuel rod cladding breach. It is not a temperature limit that implies gross rupture of fuel cladding. Additional calculations were performed to determine stresses that resulted from the fire in the welded multipurpose canister (MPC) that provides the primary boundary to release of radioactive materials. The stress calculations indicated that the MPC would not fail during the fire, and thus there would be no radioactive release for the analyzed event.

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Attachments: 1. Internal NIST Report
2. CNWRA Report

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*see previous concurrence ADAMS: ML023460565

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