SUMMARY OF TRANSPORTATION TECHNOLOGY CENTER, INC. TEST IMPLEMENTATION PLAN FOR MULTIPLE CAR TESTS OF NAVY M-290 CARS

Fuel Cycle Research & Development

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SUMMARY

This report fulfills milestone M4FT-15PN0813013 “Used Nuclear Fuel Transportation” under work package FT-15PN081301.

This report reviews the rail car testing conducted by the Association of American Railroads (AAR) Transportation Technology Center, Inc. (TTCI)[a] for multiple car (revenue service) testing of 290-ton 12-axle railcars designed to transport the U.S. Navy’s M-290 spent nuclear fuel transport casks.[b] The purpose of this review is to identify features of the TTCI multiple car testing that may inform the design of tests to characterize rail transportation shock and vibration forces on irradiated nuclear fuel—tests currently being considered by Pacific Northwest National Laboratory and Sandia National Laboratories for conduct under the auspices of the Used Nuclear Fuel Disposition Program.

The scope of data collected in the TTCI test is limited to that required to demonstrate that the railcar’s performance in the revenue service tests meets or exceeds the criteria established in AAR Standard S-2043. These data are generally limited to concerns with the integrated performance of the railcar and its suspension system in providing a high degree of confidence that the car will not derail for a broad range of conditions that occur during normal movement of the loaded railcar in commercial service by a railroad. Design of the internal components and collection of responses of the internals of the M-290 cask to rail shock and vibration forces is not included in the test plan, because the cask is not designed to transport commercial spent nuclear fuel. Therefore, there is not direct applicability of these efforts to the DOE-UFD normal conditions of rail transportation shock and vibration research efforts.

Also, the TTCI test plan does not include testing wherein the railcars would travel over greater distance, a range of track types, and varying track conditions; and be subjected to varying railroad operating conditions. Such variations would be expected to expose railcars to the much larger range of shock and vibration conditions than are likely to be experienced by the KRL 39470 and DODX 39475 cars in the planned tests. The larger range of travel conditions would be expected for rail shipments of commercial spent nuclear fuel.

Notwithstanding the differences in purpose and objectives of the TTCI and the Pacific Northwest National Laboratory and Sandia National Laboratories test projects, the TTCI test plan demonstrates TTCI’s in-depth understanding of the complexity of conducting tests of railcars under conditions that exist for railroad operations. Such understanding will be essential to the success of tests to determine rail shock and vibration forces occurring during normal transportation that will be transmitted to structures internal to casks used to transport used

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[a] TTCI - Transportation Technology Center. 2014. *Transportation Technology Center S-2043 Certification Test of Kasgro 290-Ton 12-Axle Flatcars in Multiple-Car Tests; Excerpt from TTCI,* Report P-14-028, Revised September 10, 2014 (Excerpt from Section 3.1 including Appendix C), Transportation Technology Center, Pueblo, Colorado.

[b] Hall IP, K Grub, and A Williams. 2014. “Nuclear Aircraft Carrier Inactivation - Approach for Waste Management and Exposure Reduction.” In Proceedings Newport News Shipbuilding, WM2014 Conference, March 2-6, 2014, Phoenix, Arizona, Paper 14201.

nuclear fuel and to the structures of the used nuclear fuel assemblies that are contained. As such, involvement of TTCI in future testing plans for the UFD project would be beneficial.

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ACRONYMS

AAR	Association of American Railroads
IWS	instrumented wheel-sets
SSM	System Safety Monitoring
SNF	spent nuclear fuel
TTCI	Transportation Technology Center, Inc.

SUMMARY OF TTCI "TEST IMPLEMENTATION PLAN FOR MULTIPLE CAR TESTS OF M-290 CARS

1. INTRODUCTION

This report discusses over-the-rail tests conducted by the Association of American Railroads (AAR) Transportation Technology Center, Inc. (TTCI 2014) to confirm railcars that will be used by the U.S. Navy to transport naval spent nuclear fuel contained in M-290 casks (Hall et al.2014) will meet performance requirements of AAR Standard S-2043 (AAR 2008). The AAR standard applies to all railcars used by member railroads to transport high-level radioactive materials. This report compares the purpose and design of the tests to be conducted by TTCI to those for rail shock and vibration tests being planned by Pacific Northwest National Laboratory and Sandia National Laboratories. The report also identifies TTCI's test planning and experience that may be useful to the Pacific Northwest and Sandia national laboratories' efforts.

The TTCI tests are limited in scope to determine the performance of the Navy's DODX 39475 and KRL 39470 railcars to meet the test curve requirement of the AAR standard. Tests were performed on a section of the BNSF Railroad's Raton Pass Subdivision in Colorado near the New Mexico border, about 100 miles northeast of Santa Fe, New Mexico.

Data from rail shock and vibration tests will be important to the U.S. nuclear power industry and to the U.S. Department of Energy. Both types of tests may be required to provide information to regulators regarding impacts of, and mitigations for, aging used nuclear fuel placed in dry storage, and aging of the associated storage systems on the subsequent ability to safely transport large amounts of used nuclear fuel to an off-site destination. The data will also serve to assist the Used Fuel Disposition Campaign in confirming and validating models to provide confidence in assurances of the robustness of used nuclear fuel properties for extended storage periods.

The data from these rail shock and vibration tests can be used to support predictive modeling and simulation of high burnup used fuel performance under conditions of normal transportation. The simulation results will then be supported by observations of the condition of high-burnup used nuclear fuel at the end of the Electric Power Research Institute/U.S. Department of Energy High Burnup Confirmatory Demonstration Project when the demonstration cask is opened, the fuel recovered, and the aged (and transported) fuel rods are subjected to characterization. All of these data can be used by industry in support of their extended dry storage licensing strategies and to support certification of transportation casks for shipping high-burnup and long-cooled used nuclear fuel.

2. OBJECTIVE OF TTCI RATON PASS TESTS

The objective of the TTCI tests was to measure the operating performance of two 290-ton railcars when these cars are used to transport shipping cask payloads in a mock spent nuclear fuel (SNF) train. The two railcars used in the test— the DODX 39475 and KRL 39470—were constructed for the U.S Navy. The DODX 39475 car will be used to transport an M-290 cask transporting spent nuclear fuel removed from nuclear reactors that power naval vessels. The KRL 39470 car was used to qualify the design of the Navy's S-2043 railcars to meet the AAR standard. The test plan encompasses only curve test requirements specified by Section 6.3.1 of AAR Standard S-2043 (AAR 2008).

Table 2-1 presents the AAR Standard performance criteria for the dynamic tests a railcar used to transport high-level radioactive material must satisfy. The curve test requirement of the AAR standard (300-ft. radius) was modified by the AAR/Equipment Engineering Committee (Cackovic 2009) to permit the planned tests to be performed in the 10-degree curve (574-ft. radius) at the BNSF Railroad's Raton Pass Subdivision in Colorado near the New Mexico border, about 100 miles northeast of Santa Fe, New Mexico. The maximum speed of the train was 45 mph. During transport and testing, the brakes on one half (2, 3-axle wheel-sets) of the KRL 39470 car were disengaged to accommodate the use of instrumented wheel-sets (IWS). The IWS provides information that will be used to determine wheel-to-rail interaction forces. The performance measures of interest for the tests are the dynamic testing performance criteria for railcars specified in Table 2-1 of AAR Standard S-2043 – Performance Specification for Trains Used to Carry High-Level Radioactive Material (AAR 2008).

Approximately 14 runs through the test curves were required at the following combination of conditions for test speeds of walking, 10 mph, 15 mph, and 20 mph:

- clockwise and counterclockwise through the test curve
- pushing and pulling (buff and draft) through the curve
- IWS in the leading and trailing positions.

In addition, the Raton Pass test provided an opportunity to perform functional checkout of the system safety monitoring (SSM) installed on the DODX 39475 railcar. The SSM, which is required by Section 6.2.1 of the S-2043 Standard, monitors/records wheel-bearing temperature, wheel impacts, wheel-truck hunting (car body and span bolster sensors), and car-body roll angle and acceleration (lateral, longitudinal, and vertical).

Table 2-1. Dynamic Testing Performance Criteria (from AAR Standard S-2043)

Criterion	Limiting Value	Notes
Maximum Carbody Roll Angle (degree)	4	Peak to peak
Maximum Wheel L/V Ratio	0.8	Not to exceed indicated value for a period greater than 50 millisecond (msec) and for a distance greater than 3 feet per instance
95th Percentiel Single Wheel L/V Ratio (Constant Cruving Tests Only)	0.6	Not to exceed indicated value. Applies only for constant curving tests.
Maximum Truck Side L/V Ratio	0.5	Not to exceed indicated value for a duration equivalent to 6 feet of track per instance
Minimum Vertical Wheel Load (%)	25.0	Not to fall below indicated value for a period greater than 50 msec and for a distance greater than 3 feet per instance
Peak to Peak Carbody Lateral Acceleration (g)	1.30 0.60	For non-passenger-carrying railcars For passenger-carrying railcars
Maximum Carbody Lateral Acceleration (g)	0.75 0.35	For non-passenger-carrying railcars For passenger-carrying railcars
Carbody Lateral Acceleration Standard Deviation (g)	0.13	Calculated over a 2,000-foot sliding window every 10 feet over a tangent track section that is a minimum of 4,000 feet long
Maximum Carbody Vertical Acceleration (g)	0.90 0.60	For non-passenger-carrying railcars For passenger-carrying railcars
Maximum Vertical Suspension Deflection (%)	95.0	Suspension bottoming not allowed. Maximum compressive spring travel shall not exceed 95% of the spring travel from the empty car height of the outer load coils to solid spring height
Maximum Vertical Dynamic Augment Acceleration (g)	1.0	Suspension bottoming not allowed. Vertical dynamic augment accelerations of a loaded car shall not exceed 1.0 g.

Principal features of instrumentation on the cask cars are:

- Global Positioning System (GPS) and train speed monitoring – 2 sensors
- IWS instrumentation on wheel-sets: displacement measuring instruments in spring-nests for wheel-sets A, B, C, D, E, and F on DODX 39475 and KRL 39470 railcars – 24 sensors
- Vertical and lateral accelerometers on car bodies above the span bolsters at A-and B-ends of DODX 39475 and KRL 39470 railcars – 8 sensors
- Roll gyro at B-ends of car bodies above the span bolsters of DODX 39475 and KRL 39470 railcars – 2 sensors.

In addition to instrumentation on the cask cars, TTCI installed six (total) lateral accelerometers on the A and B ends of the three 140-ton flat buffer cars used in the test train—DODX 39989, DODX 39998, and DODX 39983—and a roll gyro on the body above the span bolster of DODX 39983. The TTCI test plan states that the buffer and security cars used in the tests were existing designs (previously approved for railroad service) and the tests were not intended for qualification of these cars or for certification of an SNF train to meet the S-2043 Standard. The reason for installing instruments on the buffer cars was to monitor performance of the cars for wheel-set hunting on an as needed basis to ensure safe test conduct. The majority of measurements were on the M-290 cask cars. During previous high-speed test runs at the TTCI test track in Pueblo, Colorado, TTCI visually observed wheel-set hunting on the buffer car that was located between the instrumentation car and the first cask car.

The TTCI test plan specifies a 300 Hz sampling rate for collecting data from test instruments and requires that data be filtered at no less than 15 Hz prior to sampling. Filtering of instrument electronic signals at no less than 15 Hz is likely to be sufficient for collecting data while monitoring the mechanical dynamics of an in-motion railcar—the principal purpose of the TTCI tests. However, filters on electronic signals from instruments used in shock and vibration tests are likely to need to transmit signal frequencies of no less than 100 Hz. Nonetheless, it will be useful to understand why TTCI specifies filtering of sampled data to be at a frequency of no less than 15 Hz.

2.1 Instrumentation Car

As indicated by discussion in the test plan, TTCI used an "Instrumentation Car" in the test train. This car was placed between the first locomotive and the first buffer car in the train and was used to house data collection equipment and technicians who also observed test and buffer cars during the tests. Information provided on the TTCI website reports "typical dynamic vehicle measurements are made with a computer-equipped instrumentation car that rides along with the test car, collecting data pertinent to the test." Information included in the TTCI Test Plan for the Raton Pass tests indicates that the test car had also been used during tests of the Navy DODX and the KRL cars at the TTCI facility's test track near Pueblo, Colorado. It can be assumed that the complexity of the described Raton Pass curve tests with planned changes in direction of travel, changes in locomotive configurations, and changes in caboose configurations results in the need for the instrumentation car and availability of technicians to ensure that the data collection systems remain functional.

2.2 System Safety Monitoring

Not discussed in the TTCI test plan are data that was collected by the on-board SSM equipment on cask car DODX 39475. The SSM is designed by Lat-Lon, LLC. The SSM system monitors wheel-bearing temperature, wheel impacts, hunting (car-body and span bolster), and roll angle and car-body accelerations (lateral, longitudinal, and vertical). This is independent of the instrumentation installed by TTCI. Such data, if available could enhance the value of the data collected by the TTCI tests from the perspective of researchers who are modeling shock and vibration forces on nuclear fuel. Lat-Lon, LLC is a Colorado-based company located in the Denver-metro area (Lat-Lon 2015).

3. COMPARISON OF PLANNED DATA FROM TTCI TESTS TO DATA NEEDS FOR RAIL SHOCK AND VIBRATION TESTING

As stated in the TTCI test plan, the purpose of the Navy railcar revenue service train tests is to demonstrate that the railcar designed to transport the Navy's M-290 rail cask does not have undesirable performance in the mock SNF train (TTCI 2014). Consequently, the scope of data collected is limited to that required to demonstrate that the railcar's performance in the revenue service tests meets or exceeds the criteria established in AAR Standard S-2043. These data are generally limited to concerns with the integrated performance of the railcar and its suspension system in providing a high degree of confidence that the car will not derail for a broad range of conditions that occur during normal movement of the loaded railcar in commercial service by a railroad. Data and test design that are not available and/or will not be collected by the instrumentation listed in the TTCI test plan but that would be needed to model transmission of rail-induced shock and vibration forces to nuclear fuel include the following:

- the structural design of the Navy DODX or the KRL railcars including the specifications for the wheel-sets and suspension components
- the recorded responses of the railcar to rail shock and vibration and forces at selected locations in the railcar's structure
- the design of the cask transport cradle and the design and placement of its attachments to the railcar
- the recorded responses of the cask transport cradle to rail shock and vibration forces at selected locations in the structure of the cradle
- the design of the M-290 cask body structure including the design of the attachment of the cask body to the transport cradle
- the recorded responses of the M-290 cask to forces resulting from rail shock and vibration at selected locations on the cask's body.

Design of the internal components and collection of responses of the internals of the M-290 cask to rail shock and vibration forces is not included in the list above because the cask is not designed to transport commercial spent nuclear fuel.

Also, the TTCI test plan does not include testing wherein the railcars would travel over greater distance, a range of track types, and varying track conditions; and be subjected to varying railroad operating conditions such as what is envisioned for the DOE UFD shock and vibration testing for commercial used fuel. Such conditions would be expected to expose railcars to the much larger range of shock and vibration conditions than are likely to be experienced by the KRL 39470 and DODX 39475 cars in the Raton Pass tests. The larger range of travel conditions would be expected for rail shipments of commercial spent nuclear fuel.

Notwithstanding the differences in purpose and objectives of the TTCI and the Pacific Northwest National Laboratory and Sandia National Laboratories test projects, the TTCI test plan demonstrates TTCI's in-depth understanding of the complexity of conducting tests of railcars under conditions that exist for railroad operations. Such understanding will be essential to the success of tests currently being planned by Pacific Northwest National Laboratory and Sandia to determine rail shock and vibration forces occurring during normal transportation that will be transmitted to structures internal to casks used to transport used nuclear fuel and to the structures of the used nuclear fuel assemblies that are contained.

Determining whether to use an instrumentation car to offset the vagaries of complexity and cost for wholly autonomous instrumentation systems; having the advantage to conduct trial runs of tests on a captive track before releasing a fully instrumented test car with cask, for a cross-country over-the-rail test; and having the ability to conduct benchmark tests at a captive facility before conducting an over-the-rail test are all factors that will need to be taken into consideration. The UFD plan for shock and vibration testing of commercial fuel assemblies will consider TTCI's in-depth understanding of the complexity of conducting tests of railcars under conditions that exist for railroad operations. The involvement of TTCI and their expertise will be considered as the UFD transportation control account team prepares a test plan for shock and vibration testing of commercial used fuel under normal conditions of rail transportation.

4. REFERENCES

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