Assessing the Success of Shipping High Burn-Up Sister Rods from ORNL to PNNL

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ABSTRACT

An assessment of the shipment of ten High Burn-Up (>45 MWd/MTU) Commercial Spent Nuclear Fuel (CSNF) rods from the Oak Ridge National Laboratory (ORNL) to the Pacific Northwest National Laboratory (PNNL) using the NAC-LWT cask was performed using DOE Order 460.2A - *Departmental Materials Transportation and Packaging Management,* and its supporting manual and guide. Assessed activities were grouped as: 1) upfront planning and ensuring readiness; 2) preliminary technical evaluations; 3) transportation practices, loading, actual shipment, and unloading. All assessed activities were determined to be compliance with DOE Order 460.2A and associated guidance. An observed Best Practice was the formation of the multi-entity team tasked by DOE to ensure the success of the shipment. The team had bi-weekly meetings to ensure all necessary activities and associated issues were appropriately identified and agreed-upon by the team, then appropriately scheduled and resourced. Empowering the team to champion the success, ensured the team remained focused on successfully completing the task at hand. Although during the assessment DOE Order 460.2A and associated guidance clearly showed signs of being dated (i.e. the current version was issued in 2004, with a new version currently being drafted), the shipment was successful, and all activities were able to be successfully completed in accordance with the order and associated guidance. Assuming an increased need for small quantity (i.e., less than 25 rods) one-time CSNF shipments between the U.S. National Laboratories increase, this assessment identifies many of the key activities and methods performed in accordance with DOE Order 460.2A - *Departmental Materials Transportation and Packaging Management* that enabled this shipment to be successful.

INTRODUCTION AND BACKGROUND

The Electric Power Research Institute (EPRI) led long-term high burnup (HBU) CSNF temperature storage demonstration has the primary objective of evaluating the effect of long-term dry storage on the mechanical properties of CSNF. Performed at North Anna using a TN-32 storage cask, ORNL and PNNL are running the different PIE tests to provide fuel characterization in support of the EPRI demonstration. Since the PIE will require cutting the fuel rods, the HBU CSNF being placed in long-term storage cannot be used. Instead, similar rods must be used to provide the baseline characterization type fuel that was placed in the TN-32 storage cask [1]. With this goal in mind, the Sister Rods have similar properties as the HBU CSNF that was placed in the TN-32 casks. Although the Sister Rods did not from the same assembly, they needed to have similar characteristics (e.g., irradiation history, enrichment, clad type, etc.) [2].

Under Contract Number DE-NE0000593, Dominion Power transferred the ownership of 25 pressurized water reactor (PWR) HBU spent fuel Sister Rods to DOE [3] and the rods were shipped to ORNL.

The number and cladding of the Sister Rods are as follows [2, 5]:

- Three (3) Westinghouse Standard Zircaloy-4 rods
- Four (4) Westinghouse Low-Tin Zircaloy-4 rods
- Nine (9) Orano M5® rods,

- Nine (9) Westinghouse Zirlo™ rods

With several U.S. National Laboratories each having different advanced post irradiation examination (PIE) capabilities and expertise, ten of these rods, originally planned to be shipped as rod segments, were then shipped from ORNL to PNNL to perform different baseline tests supporting the HBU Temperature demonstration project.

This shipment was a one-time shipment, and in many ways can be considered first-of-a-kind. As a nation without a central repository for CSNF, DOE's recent experience with shipping Spent Nuclear Fuel has been limited to mostly foreign fuel and fuel associated with research reactors. This shipment differs from most current shipments in that the fuel was CSNF. Though this shipment was a single shipment of only ten rods, as DOE continues to invest in R&D programs that address the critical scientific and technical issues associated with the long-term management of CSNF, the desire/need for additional similar shipments between DOE laboratories will likely increase. In addition, with operating U.S. commercial nuclear power plants (NPP) under increased pressure to remain financially viable, the NPPs will continue to seek the ability to operate at higher and higher burn-up values. Finally, without a national repository for CSNF, the amount of U.S. stored CSNF will continue to grow and age. With several U.S. National Laboratories each having different advanced post irradiation examination (PIE) capabilities and expertise, the need for similar type, small quantity (e.g., one-time shipments of less than a dozen rods) CSNF shipments between key National Laboratories to support testing can be expected to increase. As the need for such shipments can be expected to increase, this assessment identifies many of the key activities and methods performed in accordance with DOE Order 460.2A- *Departmental Materials Transportation and Packaging Management* that enable this shipment to be successful.

DOE Order 460.2A - *Departmental Materials Transportation and Packaging Management* was used for this assessment as it establishes the requirements and responsibilities for management of Department of Energy (DOE) materials transportation and packaging to ensure the safe, secure, efficient packaging and transportation of materials. Other supporting documents which the shipment activities were assessed against include DOE Guide 460.2-1 - *Implementation Guide for Use with DOE O 460.2 Departmental Materials Transportation and Packaging Management* and DOE Manual 460.2-1A - *Radioactive Material Transportation Practices Manual*. In 2010, an intent to revise the order was issued. This DOE Order is currently being revised.

ACTIVITIES ASSESSED/EVAULATED

The assessed activities can be roughly group into three categories/stages. They are:

1. Upfront planning and readiness assurance to support effort (e.g., cask availability, capability/experience/readiness of both shipping and receiving facility with cask)
2. Initial characterizations and comparisons to Certificate of Compliance (CoC) (e.g., initial package radionuclide content, thermal loading of the package, etc.)
3. Transportation Practices, Loading, Actual Shipment, and Unloading (Activities for which the NAC was largely responsible).

Large portions of Activities 1 and 2 were iteratively performed with Activity 3 activities but significantly increasing after the initial characterization of the effort. These relationship between activities are summarized by Figure 1.

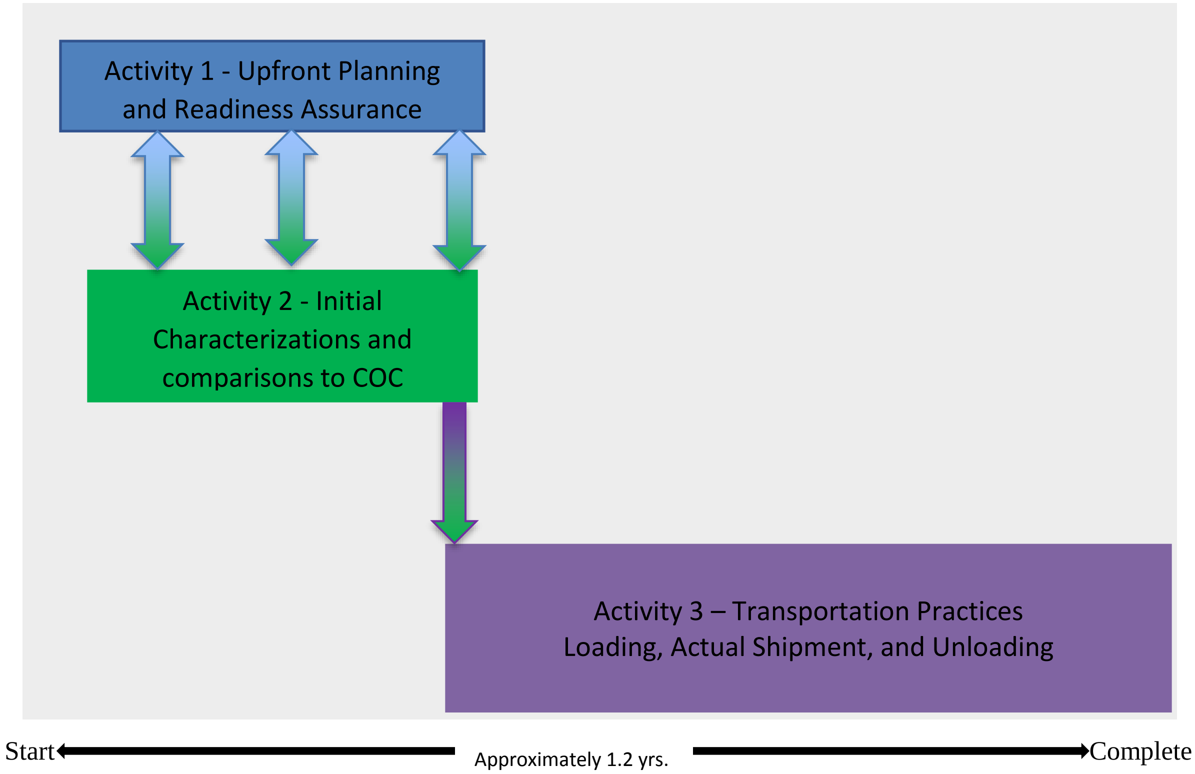

Figure 1. Sequence of Assessed Activity Groups

Upfront Planning and Readiness Assurance

Cask Determination

Initially the task was planning on shipping the ten rods cut into pieces (e.g., 6 to 10 inches long) and evaluated multiple casks. Based on various factors, both the 10-160B and the NAC-LWT emerged as the best two options. Figure 2 shows a picture of the 10-160B, while Figure 3 shows a picture of the NAC-LWT.

Figure 2. Picture of Energy Solutions 10-160B Cask

Figure 3. Vertical and Horizontal Pictures of the NAC-LWT Cask

PNNL has no waterway or rail service, therefore only a truck-based cask could be used for the shipment *(as such the DOE-M 460.2-1A Section 2.5 Mode Selection criteria did not need to be assessed).*

The NAC-LWT was identified as the only truck-based cask for shipping the CSNF with both a DOE and NRC CoC [2,4]. Since the NRC CoC for the NAC-LWT allows for shipping up to 14 damaged fuel rods, no revision to the CoC was required, also since the cask contains a transfer canister capable of holding 25 fuel rods, the ten Sister Rods or equivalent of ten Sister Rods could likely be sent in a single shipment. The initial analysis was inconclusive if the shipment could be done in one trip.

(Note: This desire to reduce the number of trips needed, to potentially result in a lower risk agrees with DOE-M 460.2-1A, Section 2.5.1. Also, DOE G 460.2-1 states that shipments should be consolidated into larger shipping quantities or units whenever such arrangements will result in transportation or administrative economies.)

The NAC-LWT transfer canister with fuel rod inserts is shown in Figure 4.

Figure 4. NAC-LWT Transport Canister with Fuel Rod Inserts

Cask Availability

Table 1 provides a summary of the NAC-LWT CoC expirations and number of casks in service [4].

Table 1. NAC-LWT CoC Expiration Dates and Number of Casks

Cask	Package ID Number	CoC Expiration Dates	Casks in Service
NAC-LWT	USA/9225/B(U)F–96 (DOE/NRC)	DOE-09/2022 NRC- 04/2020	8 owned by NAC

With eight NAC-LWT casks in existence, there was some likelihood of availability, therefore, NAC was contacted to confirm cask availability during the desired time period for the shipment.

(Note: This confirmation of availability is in agreement with DOE M 460.2. Section 2.4 which states that the cognizant DOE organization is responsible for identifying the proper packaging and taking steps to ensure that the packagings are available when needed for shipment.)

Laboratory Experience with Cask

Although the NAC-LWT is commonly used by DOE, the experience/capability both laboratory facilities also were evaluated. ORNL received the 25 Sister rods in the NAC-LWT early in 2016, confirming the capability of the ORNL to receive the cask, however ORNL did not have experience in loading the cask for shipment. PNNL had experience in receiving and unloading the cask.

Initially walks-downs were performed on both facilities (with ORNL, NAC, PNNL, and SRNL members present) to confirm that the NAC-LWT could be loaded and ship the ten rods from ORNL to PNNL, and that the rods could be received at PNNL within the NAC-LWT and readily unloaded.

Required preparations to load the NAC-LWT for shipping the Sister Rods from ORNL to PNNL was discussed by the working team and tracked in the overall project schedule. Included in the schedule was repairing/replacing the damaged floor leading to the back of the ORNL hotcell.

(Note: The observed Best Practices ensured DOE M 460.2, Section 2.3, which states that DOE identifies the need to ship, … the schedule, and other programmatic needs.)

Initial Technical Evaluations

<u>Initial Characterization</u>

The ten rods to be shipped from ORNL to PNNL were not chosen until extremely close to the actual loading and therefore could not be individually characterized in advance of the shipment. Therefore, the radionuclide characterization was based on using the 25 different fuel rods and maximizing the mass each radionuclide (i.e., this method is commonly called the developing the Hypothetical Worst-Case). The calculated Hypothetical Worst-Case Sister Rod (HWCSR) is based on a burnup of 58,000 MWd/MTU with an assumed enrichment value of 4.55 wt% U-235 and cooled for five years after removal from the reactor [6]. The calculated HWCSR content is shown in Table 2 below [6].

Table 2. Radionuclide Mass of a Hypothetical Worst-Case Sister Rod (HWCSR)

Nuclide	grams	Nuclide	grams	Nuclide	grams	Nuclide	grams	Nuclide	grams	Nuclide	grams	Nuclide	grams
Ge-72	3.13E-5	As-75	3.91E-4	Pu-237	1.96E-19	Ru-106	1.16E-2	Pr-141	3.39	Am-243	8.04E-1	Pa-233	6.22E-8
Sr-89	9.31E-14	Y-90	3.22E-4	Es-253	6.32E-40	Sn-120	1.66E-2	Eu-151	1.01E-2	Kr-85	5.75E-2	Cm-244	2.18E-1
Ru-101	2.37	Rh-103	1.35E	Se-77	2.39E-3	Te-130	1.20	Ho-165	5.31E-4	Mo-96	2.05E-1	Sr-86	2.96E-3
Sn-114	2.04E-7	Sn-115	8.71E-4	Zr-91	1.69	Sm-150	9.62E-1	Pu-244	3.50E-4	Pd-110	2.03E-1	Tc-99	2.26
Te-126	2.28E-3	I-127	1.55E-1	Sn-117	1.78E-2	Dy-162	1.16E-3	Kr-82	2.90E-3	Sn-124	3.29E-2	Cd-112	5.04E-2
Ba-135	3.36E-3	Ba-136	9.83E-2	Te-129m	2.39E-23	Pu-241	3.66	Nb-95	9.11E-11	Th-230	4.42E-5	Sb-125	6.55E-3
Pm-147	9.94E-2	Pm-148	1.26E-19	Ba-138	4.01	He-3	1.49E-4	Pd-108	6.00E-1	Cm-241	4.76E-27	Ba-134	8.60E-1
Gd-156	4.48E-1	Gd-158	9.28E-2	Tb-160	1.70E-12	Kr-80	1.33E-6	Sn-123	3.31E-8	Rb-85	3.61E-1	Nd-144	4.12
U-236	1.15E+1	Np-237	1.84E-2	Pu-238	8.95E-1	Zr-94	2.28	Xe-131	1.12	Mo-97	2.45	Gd-154	1.15E-1
Bk-249	6.63E-10	Cf-251	3.84E-8	Se-78	6.98E-3	Pd-106	1.53	Ce-142	3.44	Cd-110	2.33E-1	U-232	1.11E-5
Ge-73	6.85E-5	Ge-76	1.04E-3	Zr-92	1.86	Sb-121	1.59E-2	Sm-152	2.45E-1	Sb-124	2.38E-14	Cm-245	4.22E-2
Y-89	1.28	Zr-90	9.64E-1	Sn-118	1.69E-2	Ce-140	3.81	Er-166	1.88E-4	Cs-133	3.20	Rb-87	7.02E-1
Ru-102	2.68	Ru-104	2.00	I-129	5.19E-1	Dy-163	1.02E-3	Am-241	4.15	Eu-153	3.73E-1	Ru-99	3.97E-4
Cd-115m	3.02E-18	Cd-116	1.98E-2	La-139	3.73	Pu-242	2.23	Kr-83	1.13E-1	Th-232	2.17E-5	Cd-113	4.00E-4
Xe-126	5.08E-7	Te-128	3.01E-1	Sm-149	1.01E-2	He-4	2.20E-2	Mo-95	2.18	Cm-242	2.17E-5	Te-125	4.30E-2
Xe-136	7.10	Cs-137	3.08	Dy-160	1.56E-3	Br-81	6.20E-2	Cd-108	1.60E-6	Kr-86	5.08E-1	Nd-145	1.87
Sm-147	6.13E-1	Pm-148m	2.00E-17	Pu-239	1.46E+1	Nb-94	5.98E-6	Sb-123	2.00E-2	Mo-98	2.57	Eu-155	1.20E-2
U-237	1.14E-7	Tb-159	1.07E-2	Br-79	8.31E-6	Pd-107	8.72E-1	Eu-152	3.55E-5	Te-124	1.67E-3	U-233	2.90E-5
Cf-249	1.84E-7	Pu-236	2.29E-6	Zr-93	2.06	Sn-122	2.11E-2	Er-167	7.48E-6	Xe-134	4.72	Cm-246	5.02E-3
Ge-74	1.77E-4	Cf-252	1.05E-9	Pd-105	1.44	Xe-130	3.04E-2	Am-242m	2.97E-3	Nd-143	2.31	Sr-87	1.82E-5
Sr-90	1.27	Se-76	2.49E-5	Sn-119	1.63E-2	Ce-141	6.24E-20	Kr-84	3.26E-1	Sm-154	1.39E-1	Mo-100	2.92
Ru-103	8.29E-17	Y-91	5.92E-12	Xe-129	2.03E-4	Sm-151	3.73E-2	Zr-96	2.43	Pa-231	1.74E-6	In-113	4.87E-6
In-115	4.51E-3	Pd-104	1.06	Nd-150	5.79E-1	Dy-164	3.43E-4	Ag-109	2.87E-1	Cm-243	1.65E-3	Sn-126	7.19E-2
Te-127m	2.13E-9	Sn-116	8.42E-3	Dy-161	1.76E-3	Pu-243	3.66E-15	Te-123	2.65E-5	Rb-86	1.63E-6	Nd-146	2.31
Nd-148	1.16	Xe-128	1.87E-2	Pu-240	5.75	Se-82	9.88E-2	Xe-132	3.74	Cd-111	1.03E-1	Gd-155	3.01E-2
Gd-157	6.41E-4	Ba-137	2.46	H-3	1.09E-4	Zr-95	7.56E-11	Nd-142	9.21E-2	Cs-134	8.09E-2	U-234	4.94E-1
U-238	1.62E+3	Sm-148	5.69E-1	Se-80	3.85E-2	Ag-107	4.03E-6	Gd-152	1.04E-4	Ce-144	6.46E-3	Cm-247	1.03E-4
Cf-250	1.99E-8	Gd-160	4.57E-3	Nb-93	2.22E-5	Te-122	1.91E-3	Bi-209	2.76E-11	Eu-154	6.39E-2	Sr-88	9.59E-1
Ru-100	5.18E-1	Cd-114	5.73E-2	Sb-126	1.48E-9	Cs-135	1.41E+0	U-235	2.03E+1	Cm-248	1.08E-5		

The contents of Table 2 for a single rod would be multiplied by ten to estimate the radionuclide contents of ten HWCSR rods. Instead, however, this is not required as the CoC allows for transporting up to 25 PWR fuel rods, with a maximum 5 wt% U-235 enrichment with a maximum burn-up of 80,000 MWd/MTU with a minimum cooing time of 150 days. In addition, up to 14 of the 25 fuel rods may be classified as damaged

Based on the Table 2 calculated HWCSR, the heat load was calculated as 4.47 watts per HWCSR, with total heat load of 44.7 watts. A summary of the key radionuclides driving the heat load of the HWCSR is shown in Table 3.

Table 3. Thermal Heat Load for an HWCSR

Nuclide	gram	Ci	w/Ci	watts	Nuclide	gram	Ci	w/Ci	watts
Sr-89	9.31E-14	2.70E-9	3.46E-3	9.34E-12	Sm-151	3.73E-2	9.70E-1	7.41E-4	7.19E-4
Pm-147	9.94E-2	9.24E+1	3.67E-4	3.39E-2	Zr-95	7.56E-11	1.59E-6	5.96E-3	9.47E-9
U-236	1.15E+1	7.46E-4	2.66E-2	1.99E-5	Cm-248	1.08E-5	4.52E-8	2.76E-2	1.25E-9
Bk-249	6.63E-10	1.06E-6	1.96E-4	2.08E-10	U-235	2.03E+1	4.46E-5	2.71E-2	1.21E-6
Sm-147	6.13E-1	1.41E-8	1.37E-2	1.93E-10	Pu-244	3.50E-4	6.31E-9	2.71E-2	1.71E-10
Cf-249	1.84E-7	7.53E-7	3.74E-2	2.82E-8	Nb-95	9.11E-11	3.55E-6	4.79E-3	1.70E-8
Sr-90	1.27	1.78E+2	1.16E-3	2.06E-1	Sn-123	3.31E-8	2.72E-4	3.14E-3	8.53E-7
Ru-103	8.29E-17	2.65E-12	3.53E-3	9.37E-15	Am-241	4.15	1.41E+1	3.43E-2	4.84E-1
Te-127m	2.13E-9	2.00E-5	5.52E-4	1.11E-8	Eu-152	3.55E-5	6.39E-3	7.64E-3	4.88E-5
U-238	1.62E+3	5.52E-4	2.49E-2	1.38E-5	Am-	2.97E-3	2.97E-2	4.05E-4	1.20E-5
Cf-250	1.99E-8	2.19E-6	3.63E-2	7.94E-8	Am-243	8.04E-1	1.61E-1	3.15E-2	5.06E-3
Y-90	3.22E-4	1.74E+2	5.54E-3	9.62E-1	Kr-85	5.75E-2	2.24E+1	1.50E-3	3.36E-2
Np-237	1.84	1.30E-3	2.88E-2	3.75E-5	Th-230	4.42E-5	9.29E-7	2.77E-2	2.57E-8
Cf-251	3.84E-8	6.14E-8	3.68E-2	2.26E-9	Sb-124	2.38E-14	4.05E-10	1.33E-2	5.38E-12
Cs-137	3.08E+0	2.68E+2	1.01E-3	2.70E-1	Th-232	2.17E-5	2.39E-12	2.38E-2	5.67E-14
Pm-	2.00E-17	4.20E-13	1.28E-2	5.37E-15	Cm-242	2.17E-5	7.15E-2	3.59E-2	2.57E-3
Pu-236	2.29E-6	1.21E-3	3.42E-2	4.15E-5	Pa-231	1.74E-6	8.19E-8	2.97E-2	2.43E-9
Cf-252	1.05E-9	5.69E-7	3.52E-2	2.00E-8	Cm-243	1.65E-3	8.60E-2	3.61E-2	3.10E-3
Y-91	5.92E-12	1.48E-7	3.60E-3	5.33E-10	Cs-134	8.09E-2	1.05E+2	1.02E-2	1.07
Sb-126	1.48E-9	1.24E-4	1.84E-2	2.28E-6	Ce-144	6.46E-3	2.07E+1	6.58E-4	1.36E-2
Te-129m	2.39E-23	7.15E-19	1.80E-3	1.29E-21	Eu-154	6.39E-2	1.66E+1	9.08E-3	1.51E-1
Cs-135	1.41	1.69E-3	3.32E-4	5.61E-7	Pa-233	6.22E-8	1.31E-3	2.36E-3	3.08E-6
Tb-160	1.70E-12	1.87E-8	9.24E+1	1.73E-6	Cm-244	2.18E-1	1.76E+1	3.44E-2	6.06E-1
Pu-238	8.95E-1	1.52E+1	3.26E-0	4.96E-1	Tc-99	2.26	3.85E-2	5.01E-4	1.93E-5
I-129	5.19E-1	9.35E-5	4.77E-4	4.46E-8	Sb-125	6.55E-3	6.55	3.37E-3	2.21E-2
Pu-239	1.46E+1	9.06E-1	3.02E-2	2.74E-2	U-232	1.11E-5	2.43E-4	3.15E-2	7.65E-6
Zr-93	2.06	5.16E-3	7.29E-7	3.76E-9	Cm-245	4.22E-2	7.18E-3	3.33E-2	2.39E-4
Pu-240	5.75	1.32	3.06E-2	4.04E-2	Rb-87	7.02E-1	6.04E-8	6.58E-4	3.97E-11
Ru-106	1.16E-2	3.84E+1	5.95E-4	2.28E-2	Eu-155	1.20E-2	5.87	7.59E-4	4.45E-3
Pu-241	3.66	3.66E+2	3.20E-5	1.17E-2	U-233	2.90E-5	2.81E-7	2.86E-2	8.03E-9
Pu-242	2.23	8.71E-3	2.90E-2	2.53E-4	Cm-246	5.02E-3	1.56E-3	3.18E-2	4.95-5
Nb-94	5.98E-6	1.14E-6	1.02E-2	1.16E-8	Sn-126	7.19E-2	2.01E-3	1.08E-3	2.17E-6
Pd-107	8.72E-1	4.45E-4	5.50E-5	2.45E-8	U-234	4.94E-1	3.07E-3	2.83E-2	8.67E-5
Ce-141	6.24E-20	1.75E-15	1.47E-3	2.57E-18	Cm-247	1.03E-4	9.54E-9	3.12E-2	2.98E-10
						Heat Load per HWCSR			4.47 watts

Section 5 (ix) of the CoC, for PWR fuel rods as described in Item 5.(b)(1)(viii), sets the heat load as 2.3 kilowatts per package. As ten HWCSRs will have a total heat load of 44.7 watts, the thermal heat load limit authorized by the CoC will not be approached, and therefore is acceptable.

(Note: The development of the HWCSR characterization, and subsequent thermal loading agrees with DOE M 460.2. which states in Section 2.2. that characterization and classification of the material to be shipped are necessary to ensure that the material is shipped safely and in accordance with applicable regulations and that the material is compatible with the packaging selected for shipment. Material characterization… are performed by DOE or contractor technical staff who possess detailed knowledge of the material and who have been properly trained on the DOT regulations pertaining to classification.)

TRANSPORTATION PRACTICES

Prior to the shipment of the Sister Rods from ORNL to PNNL, PNNL awarded a contract to NAC that included providing documentation demonstrating the adequacy of the shipper and carrier training, developing a Transportation Plan and Security Plan for the shipment, arrangements with local law enforcement agencies, providing escort details, protecting the times and dates of shipments, and managing the Movement Control Center.

(Within DOE M 460.2-1A, these activities are largely are defined as part of the 14 transportation practices that establish a standardized process and framework for interacting with State, Tribal, and local authorities, other Federal agencies, and transportation contractors and carriers regarding DOE radioactive material shipments.)

Per NAC, the awarding on two different contracts, one for the upfront planning activities, and for renting the cask combined with the convenience and other associated activities, allow for the shipment to planned ahead, in case of situations arising that require a change in the shipment.

Alongside the common transportation practices contract with NAC, the DOE-NE along with PNNL ensured the shipment of the ten Sister Rods was listed on the DOE Prospective Shipment Report (PSR). DOE-NE was the shipper of record with PNNL the delegated authority to act as their agent. A separate (i.e., additional) contract was also awarded to NAC, for NAC to supply the cask, to perform the loading and transport the cask containing the rods.

(Although the PSR is not explicitly mentioned by name in DOE M 460.2-1A, DOE-NE's role in requesting that the shipment be added to the PSR is in accordance with Section 1.2 which states… For most radioactive shipments, DOE field organizations are responsible for detailed planning and for ensuring that shipments are conducted in accordance with all applicable requirements and standards. The field organizations also serve as the primary points of contact for public and stakeholder interactions. In addition, Section 2.7.1 states the designated DOE operations/area office will prepare campaign or shipment-specific public information materials, as necessary and coordinate those materials with the DOE Offices of Congressional and Intergovernmental Affairs and Public Affairs.)

Loading, Actual Shipment, and Unloading

Loading

Once PNNL received the trailer, the cask was monitored and inspected for damage. *(The inbound activities done in accordance with DOE M 460.2-1A, Section 3.2.1, which specifies inspection upon receipt.)* The selected ten Sister Rods were removed from ORNL's hot cell and horizontally loaded in the NAC-LWT. The rods were placed into the cask using the pre-developed location loading maps. When loading was complete, the NAC-LWT was closed. The NAC-LWT was then backfilled with helium. Passage of the pressure rebound test indicated the outer lid could be placed on the NAC-LWT and prepared for transport (i.e., leak check, decontamination). The cask was cleared for release and maneuvered out of the building using an air pallet and loaded into its ISO-container. (*The loading and tiedown was performed by NAC using NAC procedures in accordance with DOE M 460.2-1A, Section 3.1.9.)*

Actual Shipment

The actual transportation from ORNL to PNNL took approximately 3.5 days and was performed with no issues.

Unloading

Once PNNL received the trailer, the cask was monitored and inspected for damage. *(The inbound activities done in accordance with DOE M 460.2-1A, Section 3.2.1, which specifies inspection upon receipt.)* The NAC-LWT was removed from its ISO-container and further monitored and inspected then moved into the unloading area. The NAC-LWT cask was then moved through the truck port using the facility specific cask moving system (crane and trolley) in the Hanford building. When the cask reached the unloading area (i.e., back of the hotcell), it was then opened by NAC using NAC procedures. Each rod was removed and vented, one at a time, prior to removing the next rod. Venting of each of the rods generally required more than one day. After unloading and venting all ten rods ten rods, the cask was removed from the hot cell and surveyed and decontaminated as needed. The cask was loaded back into the ISO-container on the trailer and transported as an empty cask back to NAC, as authorized by the CoC.

Figure 6. Horizontal Unloading of NAC-LWT at PNNL

CONCLUSION

The shipment of the ten Sister Rods from ORNL to PNNL was successful, with the assessed activities performed in accordance with DOE Order 460.2A and associated guidance.

Assessed activities include:

1. Upfront planning and readiness assurance to support effort (e.g., cask availability, capability/experience/ readiness of both shipping and receiving facility with cask.)
2. Initial characterizations and comparisons to Certificate of Compliance (CoC) (e.g., initial package radionuclide content, thermal loading of the package, etc.)

3. Transportation Practices, Loading, Actual Shipment, and Unloading (Activities for which the NAC was largely responsible).

An observed Best Practice was the formation of the multi-entity team tasked by DOE to champion the success of the shipment. Initially walks-downs were performed on both facilities with ORNL, NAC, PNNL, and SRNL members present to confirm that the NAC-LWT could be loaded and ship the ten rods from ORNL to PNNL, and that the rods could be physically received at PNNL within the NAC-LWT. Because of the success of the walkdowns, the members were given a new mission by DOE-NE, that was to champion the success of the shipment. This included having bi-weekly team meetings to ensure all necessary activities and associated issues and were appropriately identified and agreed-upon by the team, then appropriately scheduled and resourced. This helped simplify communications and ensure the team remained focused on successfully completing the task at hand. Challenging and the team to champion the success, ensured the team remained focused on successfully completing the task at hand.

As DOE continues to invest in R&D programs addressing critical scientific and technical issues associated with the long-term management of CSNF, the desire/need for additional similar shipments between DOE laboratories will likely increase. In addition, with U.S. NPPs under increased pressure to remain financially viable, NPPs will continue to seek the ability to operate at higher and higher burn-up values. Finally, without a national repository for CSNF, the amount of U.S. stored CSNF will continue to grow and age. With several U.S. National Laboratories each having different advanced post irradiation examination (PIE) capabilities and expertise, the need for similar type, small quantity (e.g., one-time shipments of less than a dozen rods) CSNF shipments between key laboratories to support testing can be expected to increase. As the need for such shipments can be expected to increase, this assessment identifies many of the key activities and methods performed in accordance with DOE Order 460.2A - *Departmental Materials Transportation and Packaging Management* that enabled this shipment to be successful and associated manual and guide.

Although during the assessment DOE Order 460.2A and associated guidance clearly showed signs of being dated (i.e. the current version was issued in 2004, with a new version currently being drafted), the shipment was successful, and all activities were able to be successfully completed in accordance with the order and associated guidance

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