Proceedings of the 19th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2019
August 4-9, 2019, New Orleans, LA, USA

GE MODEL 2000 TRANSPORT PACKAGE – PAST, PRESENT, AND FUTURE

Erik Kirstein
Global Nuclear Fuel (GNF)

Christopher Kmiec
GE Hitachi Nuclear Energy (GEH)

ABSTRACT

The GE Model 2000 Radioactive Material Transport Package (GE2000) was developed at Vallecitos Nuclear Center and is designed to transport Type B quantities of radioactive materials. The GE2000 has been certified for a variety of contents over the years, with the original NRC Certificate of Compliance issued in November 1989. The original Safety Analysis Report (SAR) (1988) covered transport of byproduct, irradiated Light Water Reactor (LWR) fuel and other Special Nuclear Material (SNM) with decay heats up to 600W. The second SAR (1993) considered a High Flux Isotope Reactor (HFIR) fuel assembly as contents. The third SAR (1994) evaluated a decay heat upgrade from 600W to 2000W. The fourth SAR (1994) considered Material Test Reactor (MTR)-type fuel assemblies and Tower Shielding Reactor (TSR) fuel elements, and Revision 1 (1997) added TRIGA fuel elements. Over 100 shipments of HFIR spent fuel were made from 1996-2012 with the GE2000; approximately a dozen domestic and international SNM shipments have been made since 1993; and multiple low-level radioactive Class B/C hot cell waste shipments have been sent to the Barnwell Disposal Facility.

It was recognized by GE and the NRC that maintaining four SARs for the same shipping container was complicated and costly. To simplify things from a licensing perspective, the four SARs were consolidated into a single SAR in 2016, with irradiated fuel rods, irradiated hardware, Co-60 isotope rods, and SNM as approved contents. This consolidated SAR also introduced the High Performance Insert (HPI) to increase the shielding capability of the GE2000. Revision 1 of this SAR reduced the contents to irradiated hardware and Co-60 rods to secure timely NRC approval for a 2017 shipment of irradiated Co-60 rods using the GE2000 and HPI.

With the industry-wide development and implementation of Accident Tolerant Fuel (ATF), the GE2000 licensing basis is in the process of being updated to accommodate shipments of irradiated ATF rod segments for post-irradiation examination and testing. The GE2000 continues to safely fulfill a vital industry need. With minor package modifications, the GE2000 has been able to adapt and support a wide variety of irradiated contents over the years.

INTRODUCTION

The General Electric (GE) Model 2000 Radioactive Material Transport Package (GE2000) was developed at GE's Vallecitos Nuclear Center (VNC) in the 1980's. It was designed to transport Type B quantities of radioactive and fissile materials in solid form. It consists of an inner cask (Figure 1) and an overpack (Figure 2), and is transported exclusive use.

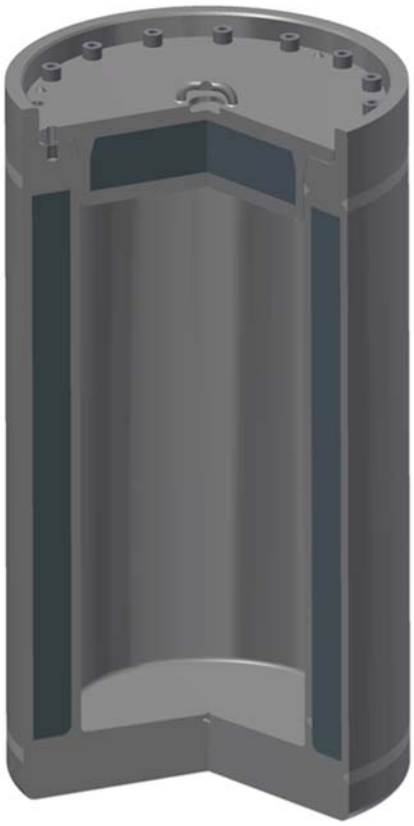

Figure 1. GE2000 Cask

The cask body (the containment vessel), is constructed of two concentric, 1-inch thick 304 Stainless Steel (SS304) cylindrical shells. The cylindrical shells are joined at the top and bottom by a SS304 forging. The annulus between the two shells is approximately 4 inches thick and filled with lead. The cask body height is approximately 71 inches and the Outer Diameter (OD) is approximately 38.5 inches. The cavity is approximately 26.5 inches in diameter and 54 inches high. The empty cask body (with closure lid) weighs about 17,000 lb.

Figure 2. GE2000 Overpack

The cask is positioned inside a protective overpack, shown in Figure 2, for transport. The overpack is constructed of two 0.5-inch thick SS304 concentric cylindrical shells, which are separated radially by eight equally spaced tubes along the length of the shells, and by two tube sections around the perimeter of the shells. A toroidal shell impact limiter made of SS304 is attached to each end of the overpack shells. The overpack opens just above the lower impact limiter for access to the cask. Additional impact protection is provided by honeycomb impact absorbers permanently positioned on the inside of the overpack at the top and bottom ends of the cask. The overpack weighs 10,200 lb and its approximate dimensions are 11 feet in height and 6 feet in diameter at the impact limiter.

GE2000 PAST

The GE2000 has a complicated licensing path because GE submitted separate Safety Analysis Reports (SARs) whenever new contents were added. The original GE2000 SAR NEDO-31581 (April 1988) [1] documents the transport of byproduct material, irradiated Light Water Reactor (LWR) fuel, and other Special Nuclear Material (SNM) with decay heats up to 600W. In addition to the cask and overpack components described above, the SAR included licensing an optional cavity liner for additional shielding. The structural evaluation in NEDO-31581 documents a Finite Element Analysis (FEA) and a series of ¼-scale drop tests to demonstrate the GE2000 met regulatory structural requirements. The original Nuclear Regulatory Commission (NRC) Certificate of Compliance (CoC) was issued in November 1989 [2].

In supporting the need for shipping High Flux Isotope Reactor (HFIR) spent fuel assemblies, a second SAR (NEDO-32229) [3] was issued by GE in July 1993. NEDO-32229 introduced a unique fuel basket and liner for transporting the HFIR assemblies, and carried forth applicable analyses via reference to the original NEDO-31581. The HFIR fuel basket and liner were both made of SS304, and designed to fit in the GE2000 cask cavity. The introduction of the HFIR fuel basket and liner did not change or introduce any new operational features to the GE2000. Decay heat remained limited to 600W. The HFIR content was approved by the NRC with the issuing of Revision 5 of the CoC [4].

It was recognized that a higher thermal content was needed to support shipments. As a result, a third SAR (NEDO-32318) [5] was issued by GE in July 1994 allowing for content or materials with a maximum decay heat of 2000W (excluding irradiated fuels). In addition, two racks to support or contain these materials were introduced in NEDO-32318, the multifunctional rack and barrel rack. Much like the introduction of the HFIR content [3], NEDO-32318 references the original NEDO-31581 where applicable. This new configuration was approved by the NRC with the issuing of Revision 8 of the CoC [6].

The fourth SAR (NEDO-32408, issued in December 1994) [7] describes and evaluates a fuel divider and basket developed for transportation of Material Test Reactor (MTR)-type fuel assemblies and Tower Shielding Reactor (TSR) fuel elements. The fuel divider separates MTR-type fuels within the rectangular cross-sections of the divider during transportation. The basket contains the TSR fuel assembly components. The original (NEDO-31581) and third (NEDO-32318) SARs are incorporated via reference in NEDO-32408 where applicable. The fourth SAR was approved by the NRC with the issuing of Revision 10 of the CoC [8]. Revision 1 of this fourth SAR (1997) added Training, Research, Isotopes, General Atomics (TRIGA) fuel elements. The TRIGA fuel elements are transported within the same fuel dividers as the MTR-type fuel assemblies. NEDO-32408 Revision 1 was approved by the NRC with the issuing of Revision 11 of the CoC [9]. The MTR, TSR, and TRIGA contents are limited to 1500W decay heat.

Over 100 shipments of HFIR spent fuel assemblies were made from 1996-2012 using the GE2000. Approximately a dozen domestic and international SNM shipments were made starting in 1993. Multiple low-level radioactive Class B/C hot cell waste shipments were sent to the Barnwell

Disposal Facility using the GE2000. These four unique SARs were maintained by GE up to Revision 26 of the CoC [10].

GE2000 PRESENT

Maintaining four separate SARs for one shipping container can be complicated and costly from a licensing perspective. After considering the planned shipments needing the GE2000, it was decided to consolidate the four SARs into one (NEDO-33866, dated April 2016) [11]. With approval from the United States Department of Energy (DOE), the previously approved contents in the second and fourth SARs (HFIR, MTR, TSR, and TRIGA fuel assemblies) were removed, instead focusing on the following contents to support current industry needs:

- Irradiated fuel rods
- Irradiated hardware and byproducts
- Co-60 isotope rods
- Special Nuclear Material (SNM)

Combined contents were allowed for shipment, with the exception of combining SNM and irradiated fuel rods. Revision 0 of NEDO-33866 also introduced the High Performance Insert (HPI) and material basket. The HPI significantly increases the shielding capability of the GE2000, using depleted uranium as its shielding material. The HPI also became an integrated part of the GE2000, with this SAR requiring use of the HPI for all content configurations. Additionally, contents were required to be shipped in one of two configurations depending on decay heat (see Table 1):

Table 1. Legacy GE2000 Transport Package Shipping Configurations

Configuration*	Material Basket	Minimum Decay Heat (W)	Maximum Decay Heat (W)
1	Optional	0	1500
2	Required	500	3000

***** The seal material defining the containment boundary (cask lid closure seal and cask port seals) is also dependent on the shipping configuration.

NEDO-33866 Revision 1 [12] was issued in September 2017, incorporating changes to the SAR as a result of responses to Requests for Additional Information (RAIs) that the NRC issued as a result of its review of Revision 0. Irradiated fuel rods and SNM were removed as contents in SAR Revision 1, leaving irradiated hardware and byproducts, and Co-60 isotope rods as the sole approved contents. The reduction of contents was done to support a 2017 shipment of irradiated Co-60 rods using the GE2000 and HPI. Additionally, all contents were limited to 1500W decay heat and Configuration 2 (see Table 1) was eliminated. The basis for this change stems from difficulty with the Configuration 2 lid seal passing leak testing at Hypothetical Accident Condition

(HAC) temperatures. However, a decay heat of 3000W is still conservatively used as the design basis for the GE2000, where applicable. There are a few exceptions as noted within NEDO-33866 Revision 1, where a decay heat of 1500W forms the design basis; although a 1500W decay heat is used in these sections, the SAR includes a demonstration that the 3000W design basis is bounding. In the event a market need exists to ship material with a decay heat of up to 3000W, GE could uprate the GE2000 by obtaining/designing and successfully testing a lid seal material that can withstand HAC temperatures.

Minor clarifications and administrative changes led GE to issue NEDO-33866 Revisions 2 and 3. The NRC approved NEDO-33866 Revision 3, issuing Revision 27 of the GE2000 CoC [13].

Since the issuance of Revision 27 of the CoC, the US DOE now maintains its own separate licensed version of the GE2000 called the Model Number 2000, Serial Number 2003 [14]; the DOE-issued certificate is based on its endorsement of the NRC's GE2000 CoC Revision 26 [10].

GE2000 FUTURE

As a result of the Fukushima accident in 2011, Congress requested that the US DOE work on developing nuclear reactor fuels with enhanced accident tolerance. The nuclear industry is very interested in the development and deployment of Accident Tolerant Fuel (ATF). As part of the DOE's ATF program, GE is preparing segmented fuel rod specimens with various GNF IronClad alloys that consist of ferritic steels, and coated Zircaloy-2 cladding (ARMOR) for irradiation in commercial Boiling Water Reactors (BWRs). The segmented rod specimens support material characterization and irradiated material testing for the ATF program. GE is endeavoring to ship irradiated ATF segments in the GE2000 for post-irradiation examination and testing.

GE is re-introducing irradiated fuel rods as authorized content by amending NEDO-33866 Revision 3. Irradiated fuel rods were previously authorized via GE2000 CoC Revision 26 [10]; however, during the NRC review of the consolidated SAR NEDO-33866 Revision 0, the NRC issued several RAIs related to the irradiated fuel rod contents. In lieu of addressing the RAIs, GE elected to remove irradiated fuel rods as content in NEDO-33866 Revision 1. In the upcoming NEDO-33866 Revision 3 amendment, GE will incorporate the irradiated fuel rod RAI responses. GE has developed a flexible and dynamic methodology to re-add the irradiated fuel rod contents, which will allow for simplified licensing updates in the future after this methodology is approved by the NRC. This methodology will support the testing of irradiated fuel rods and support the new nuclear industry initiative for higher burn-up and higher enrichment fuel.

GE has been working closely with the NRC in advance of the forthcoming GE2000 ATF-focused NEDO-33866 SAR amendment, to help ensure a successful review and timely licensing approval. GE has already participated in several teleconferences with the NRC in communicating (a) initial scheduling, (b) a high-level summary of the NEDO-33866 amendment contents and bases, and (c) the proposed technical approach. A pre-submittal meeting will take place approximately one month prior to submittal to provide the NRC an overview of the upcoming SAR amendment.

These meetings allow for constant engagement and a positive flow of communication between GE and the NRC, and aid in streamlining the review and approval process.

The addition of irradiated fuel rod segments as GE2000 contents is the first of many of GE's contributions to the ATF program. By being able to ship fuel rod segments for post-irradiation examination and testing, GE can obtain necessary information to support further development and validation of ATF rods and fuel assemblies for safe power production. The GE2000 will continue to be a viable solution for shipping a variety of irradiated contents in an economic manner.

CONCLUSIONS

GE's journey with the GE2000 shipping container has been a long one, starting in the late 1980's and continuing to evolve today. The GE2000 has been licensed to transport a wide range of contents:

- Byproduct material and irradiated hardware
- Irradiated LWR fuel
- Special Nuclear Material (SNM)
- HFIR spent fuel assemblies
- MTR-type fuel assemblies
- TSR fuel elements
- TRIGA fuel elements
- Co-60 isotope rods

GE simplified its licensing process by consolidating the four SARs into one comprehensive SAR. GE is in the process of adding irradiated fuel rod segments as approved contents to support the development of its ATF program. The GE2000 is a versatile shipping container with plenty of history and an ability to be readily adapted to provide continued support for the nuclear industry.

ACKNOWLEDGMENTS

Special thanks to Amir Vexler and Leah Crider of GNF, and Matt Feyrer and Carlos Martinez of GEH for their support.

REFERENCES

[1] NEDO-31581, Model 2000 Radioactive Material Transport Package Safety Analysis Report, Revision 0, April 1988, ADAMS Accession Number 8806070038.
[2] US Nuclear Regulatory Commission (NRC) Certificate of Compliance for Radioactive Materials Packages USA/9228/B(U)F, Revision 0, November 1989, ADAMS Accession Number 8912050051.
[3] NEDO-32229, Model 2000 Radioactive Material Transport Package HFIR Fuel Basket and Liner Safety Analysis Report, Revision 0, July 1993, ADAMS Accession Number 9308100206.
[4] US Nuclear Regulatory Commission (NRC) Certificate of Compliance for Radioactive Materials Packages USA/9228/B(U)F, Revision 5, February 1994, ADAMS Accession Number 9403020085.
[5] NEDO-32318, Model 2000 Radioactive Material Transport Package 2000 Watts Decay Heat Upgrade Safety Analysis Report, Revision 0, July 1994.
[6] US Nuclear Regulatory Commission (NRC) Certificate of Compliance for Radioactive Materials Packages USA/9228/B(U)F, Revision 8, September 1995, ADAMS Accession Number 9509200285.
[7] NEDO-32408, Model 2000 Radioactive Material Transport Package MTR-Type Fuel Divider and Tower Shielding Reactor Fuel Basket Safety Analysis Report, Revision 0, December 1994, ADAMS Accession Number 9412200082.
[8] US Nuclear Regulatory Commission (NRC) Certificate of Compliance for Radioactive Materials Packages USA/9228/B(U)F, Revision 10, July 1996, ADAMS Accession Number 9607110303.
[9] US Nuclear Regulatory Commission (NRC) Certificate of Compliance for Radioactive Materials Packages USA/9228/B(U)F, Revision 11, October 1997, ADAMS Accession Number 9711070108.
[10] US Nuclear Regulatory Commission (NRC) Certificate of Compliance for Radioactive Material Packages USA/9228/B(U)F-96, Revision 26, August 2014, ADAMS Accession Number ML14245A208.
[11] NEDO-33866, Model 2000 Radioactive Material Transport Package Safety Analysis Report, Revision 0, April 2016, ADAMS Accession Numbers ML16119A378 and ML16119A379.
[12] NEDO-33866, Model 2000 Radioactive Material Transport Package Safety Analysis Report, Revision 1, September 2017, ADAMS Accession Numbers ML17272A721, ML17272A725, and ML17272A728.
[13] US Nuclear Regulatory Commission (NRC) Certificate of Compliance for Radioactive Material Packages USA/9228/B(U)F-96, Revision 27, April 2018, ADAMS Accession Number ML18102B446.
[14] US DOE Certificate of Compliance for Radioactive Material Package USA/9228/B(U)F-96 (DOE), Revision 0, September 2015.