# ENCLOSURE 4

# M200033

# Amended Pages for NEDO-33866 GE2000 SAR Revision 6

# Non-Proprietary Information

**IMPORTANT NOTICE**

This is a non-proprietary version of Enclosure 3 to M200033, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

# ACRONYMS

| Term | Definition |
|---|---|
| 3D | Three-Dimensional |
| AEG | Average Energy Group |
| Amb. | Ambient |
| ANSI | American National Standards Institute |
| APDL | ANSYS Parametric Design Language |
| ASM | American Society for Metals |
| ASME | American Society of Mechanical Engineers |
| ASNT | American Society for Nondestructive Testing |
| ASTM | American Society for Testing and Materials |
| Aux. | Auxiliary |
| B&PVC | Boiler and Pressure Vessel Code |
| CFR | Code of Federal Regulations |
| C.G. | Center of Gravity |
| CSI | Criticality Safety Index |
| DOF | Degree-of-Freedom |
| DR | Total Dose Rate |
| DU | Depleted Uranium |
| EALF | Energy of Average Lethargy Causing Fission |
| [[ | ]] |
| FEA | Finite Element Analysis |
| FeCrAl | Iron Chromium Aluminum |
| GE | General Electric |
| GEH | GE-Hitachi Nuclear Energy Americas LLC |
| HAC | Hypothetical Accident (Transport) Conditions |
| HEPA | High Efficiency Particulate Air |
| HPI | High Performance Insert |
| H/U-235 Ratio | Hydrogen-to-U-235 Ratio |

| Term | Definition |
|---|---|
| IAEA | International Atomic Energy Agency |
| ID | Inner Diameter |
| MCNP | Monte Carlo N-Particle |
| MS | Margin of Safety |
| MSLD | Mass Spectrometer Leak Detector |
| NBS | National Bureau of Standards |
| NCT | Normal Conditions of Transport |
| NDE | Nondestructive Examination |
| Nom. | Nominal |
| NPT | National Pipe Taper (Thread) |
| NRC | Nuclear Regulatory Commission |
| OD | Outer Diameter |
| OR | Outer Radius |
| PNNL | Pacific Northwest National Lab |
| QAP | GEH Quality Assurance Program |
| S/N | Serial Number |
| SS | Stainless Steel |
| Std. | Standard |
| TCC | Thermal Contact Conductance |
| UNC | Unified Coarse |
| U-235 | Uranium-235 |
| $UO_2$ | Uranium Dioxide |
| U.S. | United States |
| USL | Upper Subcritical Limit |
| wt% | Weight Percent |

# 1 GENERAL INFORMATION

## 1.1 Introduction

The Model 2000 Radioactive Material Transport Package was developed at Vallecitos Nuclear Center. The primary use of the packaging is to provide containment, shielding, impact resistance, criticality safety, and thermal resistance for its contents during normal and hypothetical accident conditions. The packaging is designed to transport Type B quantities of radioactive materials. It complies with the Nuclear Regulatory Commission (NRC) regulations contained in the Code of Federal Regulations, Title 10, Part 71 (10 CFR 71). The package is to be shipped in all modes of transportation, except air. The Model 2000 Transport Package may only be shipped exclusive use, as discussed in Section 5.1.2. The Criticality Safety Index (CSI) is determined to be 50, as discussed in Section 6.1.3.

Calculations, engineering logic, and all related documents that demonstrate compliance with regulations are presented in subsequent sections of this report.

The GEH Quality Assurance Program (QAP) (Reference 1-1) controls design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair and modification of the packages. The NRC has approved the GEH QAP under Docket Number 71-0254 upon demonstration that the quality assurance plan meets the requirements of Subpart H of 10 CFR 71.

## 1.2 Package Description

The Model 2000 Transport Package, shown in Figure 1.2-1, is transported exclusive use, in the upright position. The approximate overall packaging dimensions are 131.5 inches in height and 72 inches in diameter. The approximate total weight of the package (packaging plus the contents) is 33,550 lb. Table 2.1-3 shows the breakdown of the component weights for the Model 2000 Transport Package.

The Model 2000 Transport Package and contents are described below:

Packaging

- Cask
- Overpack
- High performance insert (HPI)
- HPI material basket

Contents

- Solid radioactive materials

#### 1.2.1.4. HPI Material Basket

The material basket is shown in Figure 1.2-5 with an example of supplemental dunnage. The material basket is constructed of [[ ]] pattern and are identified as Item 1 on Drawing 001N8424. See Figure 1.2-6 for material basket details. The outer [[ ]] of the material basket form a composite section with the addition of [[ ]] The center location of the material basket is a developed cell, which is created by the surrounding [[ ]] To allow for the proper insertion of supplemental dunnage and facilitate fabrication, [[ ]] are inserted at the top and bottom of the developed cell and are identified as Item 2 on Drawing 001N8424. Therefore, the exterior view of the material basket shows [[ ]] facilitate loading and positioning of the material basket within the HPI cavity. Parts List 001N8424G001 is provided in Section 1.3.

### 1.2.2. Contents

#### 1.2.2.1. Radioactive Material Contents

The Model 2000 Transport Package is designed to transport Type B quantities of radioactive materials. This may include irradiated hardware and byproducts, Co-60 isotope rods, or irradiated fuel. The following are requirements for all shipments:

a) The maximum quantity of material per package shall not exceed 5,450 lb, including all cask internals and contents (defined as "payload" for purposes of this report – see Table 2.1-3).
b) All contents shipped shall be in solid form.
c) All configurations require the use of the HPI.
d) The decay heat for shipping all contents shall be limited to no more than 1500 W. However, a decay heat of 3000 W is conservatively used as the design basis for the Model 2000 Transport Package, where applicable. There are a few exceptions as noted within this SAR where 1500 W forms the basis; while a 1500 W decay heat is used in these sections, it is demonstrated that the 3000 W design basis is bounding.

The specific radioactive contents transported in the Model 2000 cask are:

1. Irradiated Hardware and Byproducts
    a. Irradiated hardware components composed of metallic alloys (e.g., stainless steels, carbon steels, Iron Chromium Aluminum (FeCrAl), nickel alloys, and zirconium alloys).
    b. Irradiated byproducts such as control rods and/or blades composed of hafnium and boron carbide.
    c. Minimum decay time shall be at least 30 days prior to shipment.
    d. Refer to loading table provided in Section 7.5.1
2. Cobalt-60 Isotope Rods
    a. Must be shipped with the HPI material basket in the upright position and confined per 2.b and demonstrated to meet NCT.

## 1.4 References

1-1 GE-Hitachi Nuclear Energy, "Quality Assurance Program Description," NEDO-11209-A, Latest NRC Approved Revision.

1-2 Parker Hannifin Corporation, "Gask-O-Seal and Integral Seal Design Handbook," CSS 5124, 2010.

**Irradiated Hardware and Byproducts**

The irradiated hardware and byproduct contents are irradiated components from typical reactor operation. These contents include:

1. Hardware: Irradiated components composed of metallic alloys (e.g., SS, carbon steels, FeCrAl, nickel alloys, and zirconium alloys). Examples include:
   - Bundle components: fuel cladding, water rods, spacers, and upper/lower tie plates
   - Reactor internals: jet pump components, core shroud samples
2. Irradiated Byproducts: Irradiated control rod blades with the following neutron poison materials:
   - Hafnium
   - Boron Carbide

**Cobalt-60 Isotope Rods**

The radioactive material in the cobalt-60 isotope rod contents is in the form of pellets or cylindrical solid rods with the source(s) evenly distributed and encapsulated in normal or special form. The isotope rods are loaded into a commercial or research reactor to irradiate the cobalt source pellets. After discharge from the reactor, the isotope rods are loaded into the Model 2000 cask for transport. These [[ ]] prior to loading into the HPI. Herein for the cobalt-60 isotope rod contents, the term 'rod' refers to a full-length rod, in its form as it is irradiated in a reactor; and the term [[ ]] in its form as it is loaded and shipped in the Model 2000 Transport Package.

### 5.2.1. Gamma Source

#### 5.2.1.1. Irradiated Fuel

To calculate gamma source strengths, ORIGEN-ARP is used, which implements the ORIGEN-S module with the GE BWR 10x10 cross section library (ge10x10-8) distributed in the SCALE6.1 code package (Reference 5-2). With the ORIGEN-ARP methodology, a problem dependent cross section library is generated by interpolating between cross sections in the SCALE6.1 pre-generated libraries. The pre-generated GE BWR 10x10 library covers initial uranium enrichments from 1.5 to 6 wt%, with burnups from 0 to 72 GWd/MTU, and moderator densities from 0.1 to 0.9 g/cm$^3$. Any mention of enrichment refers to the initial U-235 enrichment of the fuel. ORIGEN-ARP has been validated extensively for light water reactor spent fuel, as documented in the Oak Ridge National Lab report ORNL/TM-13584 (Reference 5-9).

The [[ ]] irradiated fuel contents is based on the radionuclide inventory generated from the irradiation and decay of various nuclides over time. The gamma source strength is dependent on the enrichment (E) band and burnup (B) band. In the ORIGEN-S source term analysis, for each initial enrichment band the minimum enrichment is considered, and for each burnup band the maximum burnup is considered. This generates a bounding source strength for each burnup-enrichment pairing. For the calculated source strength for each burnup-enrichment pairing the basis is 1 gram of U-235.

# 8 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This chapter describes the acceptance tests and maintenance program to be used for the Model 2000 Transport Package, required by 10 CFR 71, Subpart G. The acceptance tests are prescribed to verify materials of construction, fabrication processes, and the transport package's design adequately meets the regulations, while the maintenance program outlined in this chapter assures the packaging's performance during its service life, in full compliance with this safety analysis report.

General information related to the Model 2000 Transport Package, including package design details and contents description, is presented in Chapter 1 of this safety analysis report. For package dimensions, refer to the licensing drawings provided in Section 1.3.1. Fabrication and examination of the Model 2000 Transport Package (i.e., cask and overpack), the high performance insert (HPI) assembly, and material basket assembly, conform to the requirements of ASME Section III, as delineated in Section 8.1.

Routine inspection (prior to each loading) consists of visual examination for physical damage of all surfaces and components. Periodic or annual inspection includes visual examination, penetrant inspection of welds, and replacement of damaged or worn components, as necessary.

## 8.1 Acceptance Test

The inspection and acceptance tests are specified in the fabrication specifications and engineering drawings for the Model 2000 Transport Package and are governed by the GEH QAP (Reference 8-1). The GEH QAP has been approved by the NRC (Docket Number 71-0254) (Reference 8-2).

### 8.1.1. Visual Inspections and Measurements

Visual examinations of all dimensions are conducted during fabrication to ensure that the packaging is fabricated and assembled in accordance with manufacturing drawings and specifications. All dimensions and tolerances specified on the drawings are confirmed by measurement. Fabrication deviations are addressed in compliance with the GEH QAP for all components important to Safety Category A or B.

### 8.1.2. Weld Examinations

Visual examinations of all welds, including overpack torodial shells, are conducted during fabrication. In addition, all welds within the cask containment boundary are liquid penetration tested (root and final passes); also, the welds forming the toroidal shell are 100% radiographed. These inspections are performed to ensure no cracks, incomplete fusion, or lack of penetration, exists. Parts that do not meet the established criteria are repaired or replaced in accordance with written procedures. For Model 2000 Transport Package serial number (S/N) 2001, nondestructive examination (NDE) procedures and acceptance standards are based on the ASME Code, Section III, Subsection NG (Reference 8-3). All future fabrication will meet the requirements of the ASME Code, Section III as follows:

#### 8.2.3.2. Shielding

The shielding materials are lead and depleted uranium. The initial tests for voids during fabrication and the required radiological surveys following each loading assure shielding integrity. If the results of surveys exceed the regulatory requirements, the contents are reduced or the shipment is not initiated.

### 8.2.4. Thermal Tests

Thermal testing is only performed following initial fabrication of the cask.

### 8.2.5. Miscellaneous Tests

No additional periodic tests are required.

## 8.3 Appendix

The only appendix information for Chapter 8 is provided in Section 8.4, References.

## 8.4 References

8-1 GE Hitachi Nuclear Energy, " Quality Assurance Program Description," NEDO-11209-A, Latest NRC Approved Revision.

8-2 U.S. Nuclear Regulatory Commission (NRC), "Quality Assurance Program Approval Form for Proposed Amendment to Draft NEDO-11209 Revision 13, GE Hitachi Nuclear Energy Quality Assurance Program Description," Docket No. 71-0254, Revision 12, December 28, 2017, U.S. NRC ADAMS Accession Number ML17362A362.

8-3 American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Division I, Section III, Subsection NG, "Core Support Structures," 2010.

8-4 American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code, Division I, Section III, Subsection NB, "Class 1 Components," 2010 with addenda.

8-5 American Society of Mechanical Engineers (ASME), Boiler & Pressure Vessel Code, Division I, Section III, Subsection NF, "Component Supports," 2010.

8-6 American National Standards Institute (ANSI), "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment," ANSI N14.5, 1997.

8-7 Military Specification, "Core Material, Aluminum, for Sandwich Construction," MIL-C-7438, or Equivalent.