ENCLOSURE 6

NUH32PHB-0101, Revision 3, Design Criteria Documents for the NUHOMS 32PHB System for Storage

Calvert Cliffs Nuclear Power Plant
October 10, 2014

TRANSNUCLEAR
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DESIGN CRITERIA DOCUMENT

DOCUMENT NO:	NUH32PHB.0101	**PROJECT NAME:**	High Burn-up NUHOMS® 32PHB System for PWR Fuel
PROJECT NO:	10955	**CLIENT:**	Calvert Cliffs Nuclear Power Plant Inc. (CCNPP)

DOCUMENT TITLE:

Design Criteria Document (DCD) for the NUHOMS® 32PHB System for Storage

SUMMARY DESCRIPTION:

This document specifies design requirements for the NUHOMS® 32PHB system. The system consists of the Dry Shielded Canister (DSC), the Horizontal Storage Module, Model HSM-HB and the modified Calvert Cliffs Nuclear Power Plant Onsite Transfer Cask (CCNPP-FC TC).

This DCD supports the request of CCNPP to design an Independent Spent Fuel Storage Installation (ISFSI) to allow dry storage of high burnup fuel assemblies. This DCD presents the criteria for the NUHOMS® 32PHB DSC, HSM-HB and the CCNPP-FC Transfer Cask.

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REVISION SUMMARY

REV.	DESCRIPTION	AFFECTED PAGES
0	Initial Issue	All
1	Revision 1 corrects the headings in Table 4-4 and clarifies the source terms for reconstituted fuel assemblies. See DCR NUH32PHB-003, Rev. 0.	1-2, 11, 13, 16, 62
2	Revision 2 corrects the material of cladding for AREVA fuel assembly in Table 4-1 from Zircaloy to M5 and adds a reference for the 75g loads considered for side and end drop accident conditions. See DCR NUH32PHB-009, Rev. 0.	1, 2, 14, 38, 50
3	Revision 3 removes an incomplete statement from Section 14.0. See DCR NUH32PHB-017, Rev.0	1, 2,65

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1.0 SCOPE

This Design Criteria Document (DCD) specifies the design requirements of the NUHOMS® 32PHB Dry Shielded Canister (DSC) for storage, the HSM-HB Horizontal Storage Module, and the CCNPP-FC on-site transfer cask (TC). The system is designed for high burnup fuel, up to 62 GWD/MTU, with a maximum assembly average initial enrichment of 5% wt U-235.

General design requirements include structural, thermal, nuclear criticality safety, confinement/containment, and radiological protection criteria.

2.0 APPLICABLE DOCUMENTS

2.1 Codes and Standards

2.1.1 ASME Boiler and Pressure Vessel Code, Section II, "Materials Specifications," Parts A, B, C and D, 1998 edition with all addenda up to and including 1999 Addenda.

2.1.2 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsections NB, NG, and NC, 1998 edition with all addenda up to and including 1999 Addenda.

2.1.3 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsections NC and Appendices, Section II, Part D, 1992 edition.

2.1.4 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 1998 edition with all addenda up to and including 1999 Addenda.

2.1.5 ASME Boiler and Pressure Vessel Code, Section V, "Nondestructive Examination," 1998 edition with all addenda up to and including 1999 Addenda.

2.1.6 ASME Boiler and Pressure Vessel Code, Section IX, "Welding and Brazing Qualifications," 1998 edition with all addenda up to and including 1999 Addenda.

2.1.7 ANSI Y14.5M, "Dimensions and Tolerancing," 1982,

2.1.8 ANSI N14.5, "Leakage Tests on Packages for Shipment of Radioactive Materials," 1997.

2.1.9 ANSI N14.6, "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More", 1978 (and 1993).

2.1.10 ANSI 8.17, "Criticality Safety Criteria for Handling, Storage, and Transportation of LWR Fuel Outside reactors," 1984.

2.1.11 ANSI N16.9, "Validation of Calculational Methods for Nuclear Criticality Safety."

2.1.12 American National Standards Institute, American Nuclear Society, ANSI/ANS 57.9 - 1992, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)".

2.1.13 American Concrete Institute, ACI 349 - 97, "Code Requirements for Nuclear Safety Related Concrete Structures."

2.1.14 American Institute of Steel Construction, "AISC Manual of Steel Construction," Ninth Edition.

2.1.15 American Society of Civil Engineers, ASCE 7-95, "Minimum Design Loads for Buildings and Other Structures," (formerly ANSI A58.1).

2.1.16 American Welding Society, AWS D1.6 – 1999, "Structural Welding Code – Stainless Steel."

2.1.17 American Welding Society, AWS D1.1 – 1988, "Structural Welding Code – Steel."

2.1.18 American Welding Society, AWS A2.4 – 1986, "Weld Symbols."

2.2 Federal Regulations

2.2.1 Title 10, Code of Federal Regulations, Part 71, "Packaging and Transportation of Radioactive Materials."

2.2.2 Title 10, Code of Federal Regulations, Part 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation."

2.2.3 Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation."

2.2.4 Title 10, Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities."

2.3 NRC Bulletins, Regulatory Guides, NUREG Documents

*Note - NUREG documents are for guidance only, these documents do not impose requirements.

2.3.1 NRC Bulletin 96-04, "Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks," July 5, 1996.

2.3.2 NRC Regulatory Guide 1.13, "Spent Fuel Facility Design Basis."

2.3.3 NRC Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants."

2.3.4 NRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants."

2.3.5 NRC Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants."

2.3.6 NRC Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis."

2.3.7 NRC Regulatory Guide 1.145, "Atmospheric Dispersement Models for Potential Accident Consequence Assessments at Nuclear Power Plant," February 1989.

2.3.8 NRC Regulatory Guide 3.48, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)."

2.3.9 NRC Regulatory Guide 3.53, "Applicability of Existing Regulatory Guides to the Design and Operation of an Independent Spent Fuel Storage Installation."

2.3.10 NRC Regulatory Guide 3.60, "Design of an Independent Spent Fuel Storage Installation (Dry Storage Type)."

2.3.11 NRC Regulatory Guide 7.4, "Leakage Tests on Packages for Shipments of Radioactive Materials."

2.3.12 NRC Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels."

2.3.13 NRC Regulatory Guide 7.8, "Load Combinations for the Structural Analysis of Shipping Casks."

2.3.14 NRC Regulatory Guide 7.9, "Standard Format and Content of Part 71 Applications for Approval of Packaging for Radioactive Material."

2.3.15 Regulatory Guide 7.11, "Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 inches (0.1m)."

2.3.16 NRC Regulatory Guide 7.12, "Fracture Toughness Criteria of Base Material for Steel Shipping Cask Containment Vessels."

2.3.17 NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants," July 1980.

2.3.18 NUREG-0800, Standard Review Plan, Section 3.3.1 "Wind Loading" and Section 3.5.1.4 Missiles Generated by Natural Phenomenon."

2.3.19 NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems - Final Report," U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, January 1997.

2.3.20 NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities - Final Report," U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, March 2000.

2.3.21 NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transport Packages", April 1997.

2.3.22 NUREG/CR-6487, "Containment Analysis for Type B Packages Used To Transport Various Contents", November 1996.

2.3.23 Interim Staff Guidances (ISGs).

2.3.24 NUREG/CR-0481, SAND 77-1872, "An Assessment of Stress-Strain Data Suitable for Finite Element Elastic-Plastic Analysis of Shipping Casks," Sandia National Laboratories, September 1978.

2.3.25 NUREG/CR-2018, SAND 80-1870, "A Comparison of Analytical Techniques for Analyzing a Nuclear Spent-Fuel Shipping Cask Subjected to an End-On Impact," Sandia National Laboratories, June 1981.

2.3.26 NUREG/CR-3854, UCRL-53544, "Fabrication Criteria for Shipping Containers," Lawrence Livermore National Laboratories, March 1985.

2.3.27 NUREG/CR-3966, UCID-20639, "Methods for Impact Analysis of Shipping Containers," Lawrence Livermore National Laboratories, November 1987.

2.3.28 NUREG/CR-6407, "Quality Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety."

2.3.29 NUREG-766510, SAND76-0427, "Shock and Vibration Environments for Large Shipping Containers on Rail Cars and Trucks", Sandia National Laboratories, June 1977.

2.3.30 NUREG/CR-6322, "Buckling Analysis of Spent Fuel Basket", LLNL, May, 1995.

2.4 Technical Reports and Documents

2.4.1 NUTECH Report NUH-002, "Topical Report for the NUTECH Horizontal Modular Storage System for Irradiated Nuclear Fuel, NUHOMS® - 24," Revision 1A, July 1989.

2.4.2 CCNPP Specification SP-0564, "Spent Fuel Storage Capacity Design Specification," Revision 10.

2.4.3 CCNPP Specification SP-0564C, "NUHOMS®-32P Dry Shielded Canister," Revision 4.

2.4.4 CCNPP Specification SP-0564D, "Design Specification for NUHOMS® 32PHB DSC (High Burn-up Dry Shielded Canister)," Revision 0.

2.4.5 Calvert Cliffs Nuclear Power Plant ISFSI, "Updated Safety Analysis Report," Docket Numbers 50-317 and 50-318, Revision 17.

2.4.6 Calvert Cliffs Nuclear Power Plant ISFSI, "Appendix A to Material License SNM-2505 Technical Specification," Amendment 7, NRC Docket No. 72-8.

2.4.7 Constellation Energy, Nuclear Generation Group, Nuclear Analysis Unit, Fleet Nuclear Fuels, Memorandum, "ISFSI 32PHB Source Term Input Data," Constellation Tracking No. DE10290, TN Document No. NUH32PHB-0102.

2.4.8 Constellation Energy, Nuclear Generation Group, Nuclear Analysis Unit, Fleet Nuclear Fuels, Attachment to the Email from Eric Yin to Sue Buyaskas, Dated January 27, 2010, TN Document No. NUH32PHB-0105.

2.4.9 Constellation Energy, Nuclear Generation Group, Nuclear Analysis Unit, Fleet Nuclear Fuels, Email from John Massari to Sue Buyaskas, Dated March 16, 2010, TN Document No. NUH32PHB-0106.

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2.4.11 CCNPP Letter "DES Support for Increased Control Element Assembly (CEA) Weight," dated March 27th, 2001, NEU 01-047.

2.4.12 Transnuclear, Inc., "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," NRC Docket No. 72-1004, Transnuclear Document No. NUH-003, Revision 11.

2.4.13 Transnuclear Inc., "Updated Final Safety Analysis Report for the NUHOMS® HD Horizontal Modular Storage System for Irradiated Nuclear Fuel", NRC Docket No. 72-1030, Revision 1.

2.4.14 Transnuclear Inc., "Design Criteria Specification (DCS) for the CoC 72-1004 (OS197 and OS200) On-Site Transfer Casks," Transnuclear Specification No. NUH06-0110, Revision 1.

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2.4.16 Nuclear Regulatory Commission, "Safety Evaluation Report of Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," USNRC Docket Number 72-1004, Amendment No. 10.

2.4.17 Transnuclear, Inc., "NUHOMS® System Operations Manual," NUH-07-118, Revision 5.

2.4.18 Transnuclear, Inc., "Fabrication Specification for NUHOMS® System Dry Shielded Canister," TN Specification NUH-03-105, Revision 10.

2.4.19 Transnuclear, Inc., "Precast Concrete Construction for NUHOMS® HSM," TN Specification NUH-03-0214, Revision 3.

2.4.20 Schwartz, M. W., Witte, M. C., "Spent Fuel Cladding Integrity During Dry Storage", UCID-21181, Lawrence Livermore National Laboratory, September 1987.

2.4.21 Transnuclear West (TNW) Inc., Document No. 31-B9604.97-003, dated December 19, 1997; Addendum to TNW Document No. 31-B9604.0102, Rev. 2, An Assessment of Chemical, Galvanic and Other Reactions in NUHOMS® Spent Fuel Storage and Transportation Casks.

2.4.22 Nuclear Assurance Corporation, "Domestic Light Water Reactor Fuel Design Evolution," Volume III, September 1981.

2.4.23 Adkins, H. E. Jr., et al, "Spent Nuclear Fuel Structural Response When Subject to an End Impact Accident," PVP2004-2804, PVP-Vol. 483, Transportation, Storage, and Disposal of Radioactive Materials—2004, July 25-29, 2004, San Diego California USA

2.4.24 Geelhood, K. J. and Beyer, C. E., "PNNL Stress/Strain Correlation for Zircaloy," Pacific Northwest National Laboratory, March 2005.

2.4.25 Lawrence Livermore National Laboratory, "Dynamic Impact Effects on Spent Fuel Assemblies," LLNL/UCID Report No. 21246, October 1987.

2.4.26 Kaufman, J.G., ed., "Properties of Aluminum Alloys: Tensile, Creep, and Fatigue Data and High and Low Temperatures", The Aluminum Association (Washington, D.C.) and ASM International (Metals Park, Ohio), 1999.

2.4.27 ASME NQA-1, "Quality Assurance Requirements for Nuclear Facility Applications".

2.4.28 Welding Research Council (WRC), "Local Stresses in Spherical and Cylindrical Shells Due To External Loadings", Bulletin 107 August 1965, March 1979 Revision.

2.4.29 Tietz, T. E., "Determination of the Mechanical Properties of a High Purity Lead and a 0.058 Percent% Copper-Lead Alloy," Presented at the Sixty Second Annual Meeting of the ASTM Society, June 1959, ASTM 59, 1052.WADC Technical Report 57-695, ASTIA Document No. 151165, Stanford Research Institute, Menlo Park, CA, April, 1958.

2.4.30 Constellation Energy, Nuclear Generation Group, Calculation, "Comparison of the Radiological, Thermal, and Reactivity Characteristics of Assemblies with Missing or Inert Fuel Rods with the 32P ISFSI DSC Design Basis," CCNPP, Calculation No. CA06367, Rev. 0000, TN Document No. NUH32PHB-0109.

2.4.31 Constellation Energy, Nuclear Generation Group, CCNPP Site, ECP Document, ES200100208, Rev. 0000, TN Document No. NUH32PHB-0108.

3.0 GENERAL SYSTEM DESCRIPTION

The NUHOMS® 32PHB system consists of the 32PHB DSC, the HSM-HB and the CCNPP-FC TC. The 32PHB system is designed to allow transfer of spent fuel in the 32PHB DSC using the CCNPP-FC TC, provide for storage of spent fuel in an HSM-HB. The system will be licensed for storage in accordance with the requirements of Title 10, Part 72 (10 CFR 72) of the Code of Federal Regulations, via licensing amendment to the CCNPP ISFSI Final Safety Analysis Report [2.4.5]. The 32PHB DSC will accommodate up to 32 intact CE 14x14 or equivalent reload spent fuel assemblies (including fuel with stainless steel replacement rods) with and without axial blankets.

The NUHOMS® 32PHB DSC design is similar to the NUHOMS® 32P DSC design documented in [2.4.5] with the maximum decay heat load per canister increased from 21.12 kW to 29.6 kW. The DSC has a nominal outside diameter and length (including grapple ring) of 67.25 inches and 176.5 inches, respectively. Solid aluminum transition rails are incorporated into the 32PHB basket to accommodate heat loads up to 29.6 kW.

The NUHOMS® 32PHB DSC consists of a shell assembly, which provides confinement and shielding, and an internal basket assembly, which locates and supports the fuel assemblies, transfers the heat to the cask body wall, and provides for criticality control as necessary to satisfy nuclear criticality safety requirements. The basket is a tube assembly, with aluminum and poison plates in between the tubes for heat transfer and criticality control. Except for the solid aluminum rails, the 32PHB basket is identical to the 32P basket documented in [2.4.5].

The HSM-HB to be used for the 32PHB system is similar to the horizontal storage module HSM-H with flat stainless steel heat shields described in the UFSAR for standardized NUHOMS® System [2.4.12], Appendix P and the UFSAR for NUHOMS® HD System [2.4.13]. In these systems the HSM-H is used to store a 24PTH DSC (with a maximum canister length of 192.55" and canister diameter of 67.19"), or a 32PTH DSC (with a maximum canister length of 185.75" and canister diameter of 69.75"). As noted above the maximum length of a 32PHB DSC (including the grapple ring) is 176.5". The HSM-H internal cavity design has the flexibility to accommodate a shorter canister length with minor changes to the design of the rail spacer at the back end of the steel support structure. The HSM-HB with these modifications and flat stainless steel heat shields shall be evaluated as part of the 32PHB system analysis.

The transfer cask to be used for the 32PHB is the CCNPP-FC TC. The nominal cavity inner diameter and inner cavity length of CCNPP-FC TC are 68.0" and 173.5", respectively. These dimensions are identical to the corresponding dimensions of the existing CCNPP TC. The cask lid of CCNPP-FC TC is redesigned to improve the cask's thermal performance. The new lid contains small openings around the periphery that vent out forced air that is injected at the bottom of the cask (through the ram access opening) and circulates up through the cask's length through the cask/DSC annulus. A 0.5 inch thick spacer disc with wedge shaped protrusions is installed at the bottom of the TC to facilitate air flow coming through the ram access opening to the annular space around the DSC.

4.0 DESIGN BASIS FUEL CHARACTERISTICS

The NUHOMS® 32PHB DSC shall be designed for PWR fuel assemblies with characteristics as described in Table 4-1 and Table 4-2.

The 32PHB DSC is designed to accommodate up to 32 intact PWR fuel assemblies. The DSC payload may not include non-fuel assembly hardware components such as Control Element Assemblies (CEAs).

The bounding radiological source terms for fuel assemblies are shown in Table 4-4, Table 4-5, and Table 4-6. Based on evaluations performed in [2.4.30] and [2.4.31], the source terms presented in these tables are bounding for reconstituted fuel assemblies provided that the restriction on the number of reconstituted fuel rods and requirements for additional cooling time specified in [2.4.30] and [2.4.31] are followed.

Table 4-1
Fuel Assembly Design Characteristics

Assembly Class	Standard CE 14x14	Value Added Pellet (VAP)	AREVA
Clad Material [2.4.7]	Zircaloy-4	Zircaloy-4	M5
Pellet stack UO_2 density (%TD) [2.4.7]	93.5 - 96%	96%	96%
Number of Rods	176	176	176
Number of Water Holes	5	5	5
Fuel rod pitch (in) [2.4.7]	0.580	0.580	0.580
Pellet OD (in) [2.4.7]	0.3765	0.381	0.3805
Clad ID (in) [2.4.7]	0.384	0.388	0.387
Clad OD (in) [2.4.7]	0.440	0.440	0.440
Guide tube ID (in) [2.4.7]	1.035	1.035	1.035
Guide tube OD (in) [2.4.7]	1.115	1.115	1.115
Maximum Enrichment (wt% U-235) [2.4.7]	4.50%	5%	5%

Table 4-2
Fuel Types Characteristics

	Description	Value
Physical Characteristics	Maximum Assembly Weight	1375 lbs
	Maximum Assembly Length (including irradiation growth)	158 inches
	Number of Grid Spacers	9
	Nominal Assembly Envelope	8.25 inches square
	Active Fuel Length	136.7 inches
Radiological Source	Maximum Peak Pin Burnup	62 GWd/MTU
	Assembly Average Burnup	58 GWd/MTU
	Maximum initial enrichment	5.0 wt% U-235
	Minimum initial enrichment	2.0 wt% U-235
	Maximum Uranium Content	420 kg/assembly
	Minimum Cooling Time	As needed to reach 0.8 to 1.0 kW per Assembly. See Figure 4-1.
	Nominal Specific Power	32.2 MW/MTU
	Maximum Neutron Source per Assembly	6.66×10^8 n/sec
	Maximum In-core Gamma Source per Assembly	7.45×10^{15} γ/sec
Thermal Source	Maximum Heat Load per Assembly depending on Zone, See Figure 4-1	0.8 to 1.0 kW

Table 4-3
Fuel Assembly Region Lengths

Unit inch [1]

Fuel Type	**Fuel Type AREVA**	**Fuel Type Standard**	**Fuel Type Guardian**	**Fuel Type VAP(Guardian)**
Region	Region Length	Region Length	Region Length	Region Length
Top Ending Fitting	6.469	5.766	5.491	6.483
Plenum	9.217	10.525	9.804	8.816
Active Fuel	136.7	136.7	136.7	136.7
Bottom Ending Fitting	4.486	4.25	5.246	4.873
Sum	156.872	157.241	157.241	156.872

Notes:

(1) The data in Table 4-3 is provided by Constellation Energy, Nuclear Generation Group in [2.4.8].

Table 4-4
Bounding Neutron Sources per Fuel Assembly for 1000 Watt and 800 Watt

		1000 W	800W	Adjusted for 800W
Emin (MeV)	Emax (MeV)	Neutrons/Sec	Neutrons/Sec	Neutrons/Sec
1.40E+01	2.00E+01	0.00E+00	0.00E+00	0.00E+00
1.20E+01	1.40E+01	1.18E+05	9.00E+04	9.46E+04
1.00E+01	1.20E+01	7.20E+05	5.52E+05	5.80E+05
8.00E+00	1.00E+01	2.44E+06	1.87E+06	1.97E+06
7.50E+00	8.00E+00	1.97E+06	1.51E+06	1.59E+06
7.00E+00	7.50E+00	2.64E+06	2.02E+06	2.12E+06
6.50E+00	7.00E+00	3.90E+06	2.99E+06	3.14E+06
6.00E+00	6.50E+00	5.83E+06	4.47E+06	4.70E+06
5.50E+00	6.00E+00	8.74E+06	6.70E+06	7.04E+06
5.00E+00	5.50E+00	1.18E+07	9.00E+06	9.46E+06
4.50E+00	5.00E+00	1.63E+07	1.25E+07	1.31E+07
4.00E+00	4.50E+00	2.13E+07	1.63E+07	1.71E+07
3.50E+00	4.00E+00	3.42E+07	2.63E+07	2.76E+07
3.00E+00	3.50E+00	4.24E+07	3.26E+07	3.43E+07
2.50E+00	3.00E+00	5.51E+07	4.25E+07	4.47E+07
2.35E+00	2.50E+00	2.08E+07	1.61E+07	1.69E+07
2.15E+00	2.35E+00	2.92E+07	2.25E+07	2.36E+07
2.00E+00	2.15E+00	2.32E+07	1.79E+07	1.88E+07
1.80E+00	2.00E+00	3.39E+07	2.60E+07	2.74E+07
1.66E+00	1.80E+00	2.62E+07	2.01E+07	2.11E+07
1.57E+00	1.66E+00	1.74E+07	1.34E+07	1.41E+07
1.50E+00	1.57E+00	1.45E+07	1.12E+07	1.17E+07
1.44E+00	1.50E+00	1.24E+07	9.53E+06	1.00E+07
1.33E+00	1.44E+00	2.49E+07	1.91E+07	2.01E+07
1.20E+00	1.33E+00	3.08E+07	2.36E+07	2.48E+07
1.00E+00	1.20E+00	4.78E+07	3.67E+07	3.86E+07
8.00E-01	1.00E+00	4.65E+07	3.57E+07	3.75E+07
7.00E-01	8.00E-01	2.69E+07	2.06E+07	2.17E+07
6.00E-01	7.00E-01	2.68E+07	2.06E+07	2.16E+07
5.12E-01	6.00E-01	2.31E+07	1.77E+07	1.86E+07
5.10E-01	5.12E-01	5.25E+05	4.02E+05	4.23E+05
4.50E-01	5.10E-01	1.57E+07	1.21E+07	1.27E+07
4.00E-01	4.50E-01	1.31E+07	1.01E+07	1.06E+07
3.00E-01	4.00E-01	2.53E+07	1.94E+07	2.04E+07
2.00E-01	3.00E-01	5.23E+03	4.72E+03	4.96E+03
1.50E-01	2.00E-01	2.61E+03	2.36E+03	2.48E+03
1.00E-01	1.50E-01	2.61E+03	2.36E+03	2.48E+03
7.50E-02	1.00E-01	0.00E+00	0.00E+00	0.00E+00
7.00E-02	7.50E-02	0.00E+00	0.00E+00	0.00E+00
6.00E-02	7.00E-02	0.00E+00	0.00E+00	0.00E+00
4.50E-02	6.00E-02	0.00E+00	0.00E+00	0.00E+00
3.00E-02	4.50E-02	0.00E+00	0.00E+00	0.00E+00

2.00E-02	3.00E-02	0.00E+00	0.00E+00	0.00E+00
1.00E-02	2.00E-02	0.00E+00	0.00E+00	0.00E+00
	Total	**6.66E+08**	**5.12E+08**	**5.38E+08**

Notes:
(1) Neutron Source is provided by Constellation Energy, Nuclear Generation Group in [2.4.9].

Table 4-5
Bounding Gamma Source Terms (Gamma/Sec) per Fuel Assembly for 800 Watt

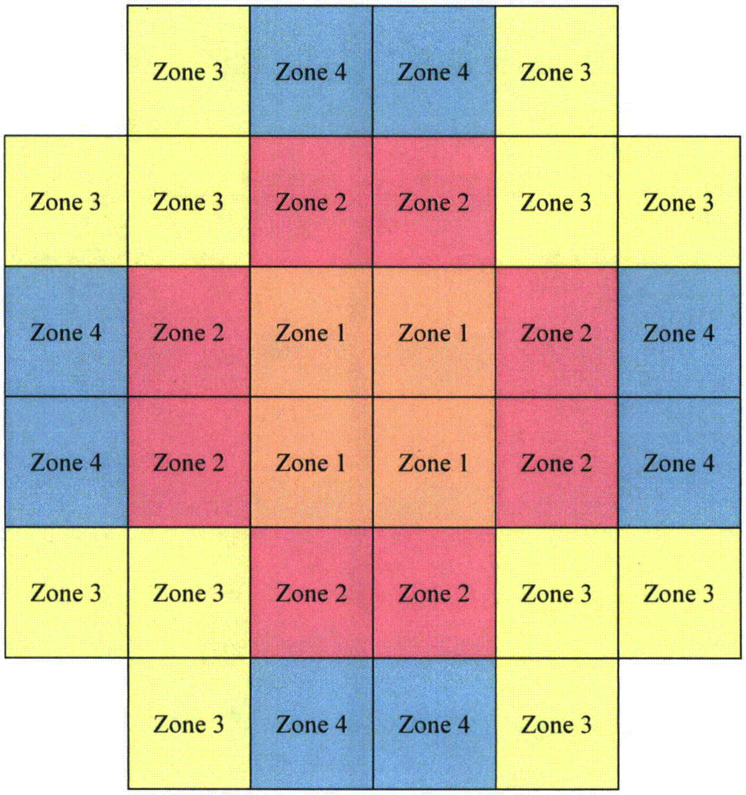
			Active Fuel	**LEF**	**Plenum**	**UEF**	**Total**
E_{min} (MeV)		**E_{max} (MeV)**	**Gamma/sec**	**Gamma/sec**	**Gamma/sec**	**Gamma/sec**	**Gamma/sec**
0.00E+00	to	2.00E-02	1.51E+15	9.76E+11	2.14E+11	4.75E+11	1.51E+15
2.00E-02	to	3.00E-02	3.33E+14	3.96E+12	1.19E+11	3.88E+12	3.41E+14
3.00E-02	to	4.50E-02	3.94E+14	7.77E+11	3.79E+10	7.20E+11	3.96E+14
4.50E-02	to	7.00E-02	2.66E+14	7.49E+10	1.94E+10	2.64E+10	2.66E+14
7.00E-02	to	1.00E-01	1.89E+14	3.58E+10	9.20E+09	1.27E+10	1.89E+14
1.00E-01	to	1.50E-01	2.08E+14	3.37E+10	4.77E+09	2.27E+10	2.08E+14
1.50E-01	to	3.00E-01	1.69E+14	2.51E+11	6.58E+09	2.48E+11	1.69E+14
3.00E-01	to	4.50E-01	8.96E+13	1.47E+12	3.29E+10	1.47E+12	9.26E+13
4.50E-01	to	7.00E-01	2.26E+15	1.89E+12	4.20E+10	1.89E+12	2.26E+15
7.00E-01	to	1.00E+00	4.63E+14	8.46E+10	1.05E+11	1.18E+10	4.63E+14
1.00E+00	to	1.50E+00	8.67E+13	2.08E+13	7.37E+12	1.85E+12	1.17E+14
1.50E+00	to	2.00E+00	3.70E+12	8.59E+03	4.04E+03	1.91E+03	3.70E+12
2.00E+00	to	2.50E+00	2.91E+12	1.10E+08	3.89E+07	9.75E+06	2.91E+12
2.50E+00	to	3.00E+00	7.19E+10	1.70E+05	6.04E+04	1.51E+04	7.19E+10
3.00E+00	to	4.00E+00	8.87E+09	5.23E-10	1.04E-13	1.32E-12	8.87E+09
4.00E+00	to	6.00E+00	3.48E+06	0.00E+00	0.00E+00	0.00E+00	3.48E+06
6.00E+00	to	8.00E+00	4.00E+05	0.00E+00	0.00E+00	0.00E+00	4.00E+05
8.00E+00	to	1.10E+01	4.60E+04	0.00E+00	0.00E+00	0.00E+00	4.60E+04
		Total	**5.97E+15**	**3.03E+13**	**7.97E+12**	**1.06E+13**	**6.02E+15**

Notes:
(1) Gamma Source is provided by Constellation Energy, Nuclear Generation Group in [2.4.9].

Table 4-6
Bounding Gamma Source Terms (Gamma/Sec) per Fuel Assembly for 1,000 Watt

			Active Fuel	LEF	Plenum	UEF	Total
E_{min} (MeV)		E_{max} (MeV)	Gamma/sec	Gamma/sec	Gamma/sec	Gamma/sec	Gamma/sec
0.00E+00	to	2.00E-02	1.83E+15	1.20E+12	2.60E+11	5.96E+11	1.83E+15
2.00E-02	to	3.00E-02	4.03E+14	5.01E+12	1.49E+11	4.91E+12	4.13E+14
3.00E-02	to	4.50E-02	4.78E+14	9.52E+11	4.59E+10	8.85E+11	4.80E+14
4.50E-02	to	7.00E-02	3.22E+14	9.05E+10	2.33E+10	3.25E+10	3.23E+14
7.00E-02	to	1.00E-01	2.31E+14	4.32E+10	1.10E+10	1.56E+10	2.31E+14
1.00E-01	to	1.50E-01	2.58E+14	4.11E+10	5.74E+09	2.79E+10	2.58E+14
1.50E-01	to	3.00E-01	2.07E+14	3.08E+11	8.05E+09	3.05E+11	2.08E+14
3.00E-01	to	4.50E-01	1.11E+14	1.81E+12	4.04E+10	1.81E+12	1.14E+14
4.50E-01	to	7.00E-01	2.79E+15	2.33E+12	5.16E+10	2.33E+12	2.79E+15
7.00E-01	to	1.00E+00	6.42E+14	1.14E+11	1.41E+11	1.59E+10	6.42E+14
1.00E+00	to	1.50E+00	1.14E+14	2.49E+13	8.85E+12	2.21E+12	1.50E+14
1.50E+00	to	2.00E+00	4.94E+12	1.97E+04	8.73E+03	5.22E+03	4.94E+12
2.00E+00	to	2.50E+00	3.82E+12	1.31E+08	4.67E+07	1.17E+07	3.82E+12
2.50E+00	to	3.00E+00	1.00E+11	2.03E+05	7.24E+04	1.81E+04	1.00E+11
3.00E+00	to	4.00E+00	1.24E+10	1.54E-09	1.71E-13	2.18E-12	1.24E+10
4.00E+00	to	6.00E+00	6.85E+06	0.00E+00	0.00E+00	0.00E+00	6.85E+06
6.00E+00	to	8.00E+00	7.88E+05	0.00E+00	0.00E+00	0.00E+00	7.88E+05
8.00E+00	to	1.10E+01	9.07E+04	0.00E+00	0.00E+00	0.00E+00	9.07E+04
		Total	**7.40E+15**	**3.68E+13**	**9.58E+12**	**1.31E+13**	**7.45E+15**

Notes:
(1) Gamma Source is provided by Constellation Energy, Nuclear Generation Group in [2.4.9].



Heat Zone Level	No of FA	kW/FA	Total
1	4	0.8	3.2
2	8	1.0	8.0
3	12	1.0	12.0
4	8	0.8	6.4
Total Heat Load, kW			**29.6**

Figure 4-1 Heat Load Zone Configuration for the Maximum Heat Load

Note: Four zones are employed to denote an increasing importance to dose rates, where Zone 1 represents the least important zone and Zone 4 represents the most important zone.

5.0 GENERAL DESIGN REQUIREMENTS

The general requirements of the NUHOMS® 32PHB canister are listed below. Specific component requirements are provided in subsequent sections.

- The NUHOMS® 32PHB canister shall meet the following requirements:
  - The "on-the-hook" weight limit shall not exceed the 125 ton crane limit. Draining of the cavity prior to removal from the pool may be used to meet the weight limits. During water removal a Helium or Nitrogen gas blanket is used to avoid fuel exposure to air.
  - The maximum per assembly heat load shall be 1.0 kW. The maximum heat load per canister shall be 29.6 kW. Zoning is used to accommodate total DSC heat loads up to 29.6 kW.
  - Air circulation in the TC/DSC annulus may be used to maintain cladding within the allowed temperature limits of ISG-11 Rev. 3. The time limit to initiate air circulation following drainage of the TC/DSC annulus shall be greater than or equal to 20 hours for the maximum heat load. The heat load zone configuration for the maximum heat load is shown in Figure 4-1. In addition to evaluation of the design basis heat load, the design shall also identify maximum heat loads with uniform heat load zoning configurations for the following conditions:
    - Time limit to initiate air circulation is greater than or equal to 48 hours
    - Time limit to initiate air circulation is greater than or equal to 72 hours
  - Average fuel assembly burnups up to 62 GWd/MTU to bound the data shown in Table 4-2.
  - Maximum 5.0 wt.% initial U-235 fuel enrichment. Minimum 2.0 wt % U-235
  - Boron loading in the pool as function of U-235 enrichment (between 2450 and 2550 ppm)
- The CCNPP-FC TC shall contain similar features, such as the spacer disc, airflow adaptor, and slotted lid, required for air circulation as in the OS197FC TC.
- The 32PHB DSCs shall be stored only in the HSM-HB.
- The CCNPP-FC TC shall be used to transfer the 32PHB DSC from the Auxiliary Building to the HSM-HB site.
- The criteria and evaluations to be performed for the 32PHB DSC are similar to those used for the 32P documented in [2.4.3].

5.1 System Design Features and Considerations

This section describes design features and considerations for the 32PHB Canister, the HSM-HB and the CCNPP-FC transfer cask.

5.1.1 Canister Features and Considerations

The 32PHB canister shall meet the criteria below:

- Store up to 32 intact CE 14x14 Standard or VAP and/or AREVA 14x14 PWR spent fuel assemblies.
- For criticality control poison sheets shall be incorporated into the basket design. No structural credit shall be taken for the poison sheets.
- Nominal external diameter of 67.25" and a nominal shell thickness of 0.63".
- Nominal canister length of 176.50", including the grapple ring on the outer bottom cover plate.
- Nominal internal cavity length of 159".
- Carbon (or stainless) steel end shield plugs with a lead core at both ends to reduce occupational dose levels.
- Vent and siphon block shall be welded and integrated to the top shield plug assembly, similar to the HD license designs [2.4.13].
- The inner diameter of the vent and siphon ports shall be approximately 1 inch.
- All carbon steel surfaces exposed to the fuel pool shall be electroless nickel coated to minimize the effects of hydrogen generation during fuel loading operations.
- Proper interface shall be provided with the CCNPP-FC transfer cask and HSM-HB.

5.1.1.1 Weight Requirements

Limit the maximum lifted load to less than 125 tons for the worst lift configuration with the heaviest fuel type. The maximum under-the-hook weight shall consider the following lift configurations:

Lift 1—from Decon Area to Fuel Pool

Lift 1 consists of the transfer cask with an unloaded DSC. Both the DSC and the Cask/DSC annulus are filled with water. The cask is lifted from the cask decon area to the spent fuel pool. Its configuration is as follows:

- Transfer Cask
  - Top cover plate assembly removed
  - Ram access cover plate installed
- DSC
  - Internal basket assembly installed
  - Shield plug removed
  - Top cover plate not installed
- Lifting yoke assembly with or without top shield plug attached and yoke extension slings (as applicable)

- Demineralized water in cask/DSC annulus (includes water above DSC)
- Borated water in DSC cavity (partially displaced by basket assembly)

Lift 2—from Fuel Pool to Decon Area

Lift 2 consists of the transfer cask and DSC loaded with spent fuel assemblies. Both the DSC and the Cask/DSC annulus are filled with water. The cask is lifted from the spent fuel pool to the cask decon area. Its configuration is as follows:

- Transfer Cask
  - Top cover plate assembly removed
  - Ram access cover plate installed
- DSC
  - Internal basket assembly installed
  - Top shield plug installed
  - Top cover plate not installed
- Fuel assemblies loaded
- Lifting yoke assembly and yoke extension slings (as applicable)
- Demineralized water in cask/DSC annulus (includes water above DSC)
- Borated water in DSC cavity (partially displaced by basket assembly and fuel assemblies)

Lift 3—from Decon Area to Transfer Trailer

Lift 3 consists of the transfer cask and DSC loaded with spent fuel assemblies. Both the DSC and the Cask/DSC annulus are dry. The cask is lifted from the cask decon area to the transfer trailer. Its configuration is as follows:

- Transfer Cask
  - Top cover plate assembly installed
  - Ram-access cover-plate installed
  - Annulus is vented to atmosphere.
- DSC
  - Internal basket assembly installed
  - Top shield plug installed
  - Top cover plate installed
- Fuel assemblies loaded
- Lifting yoke assembly without yoke extension slings
- Cask/DSC annulus and DSC cavity drained. Annulus is vented to atmosphere

5.1.2 HSM-HB Features and Considerations

5.1.2.1 HSM-HB Transfer Operation Features

- Provide a round access opening compatible with the canister nominal outer diameter of 67.25 inches (32PHB).
- The access opening horizontal centerline shall be nominally 8 feet 6 inches above ground to properly interface with the NUHOMS® transfer equipment.
- Provide a shielded door design (similar to HSM-H, Type B) that facilitates handling during canister transfer operations. Thickness and composition shall be established to meet the shielding requirements of Section 12.0.
- Interface with the modified on-site transfer cask (CCNPP-FC TC). Provide a means to restrain the transfer cask during canister insertion/withdrawal operations. This shall consist of embedded anchors capable of carrying a load of 55 kips (each side).
- Provide a recessed cask docking surface to shield the end of the cask during canister transfer. Provide cask alignment targets on the exterior surface of the front wall on the cask horizontal and vertical centerlines.
- Incorporate a hardened stainless steel surface into the support structure to facilitate canister sliding and minimize gouging during transfer.

5.1.2.2 HSM-HB Storage Operation Features

- Provide support for a canister with a nominal outside diameter of 67.25 inches and nominal length of 176.50 inches. The HSM-HB design shall be based on a bounding dry loaded weight of 95 kips per canister.
- Provide seismic restraints to transfer horizontal loads during a seismic event to the concrete structure.
- Provide structural resistance to protect the DSC from blast explosion.

5.1.2.3 HSM-HB Thermal Performance Features

- Provide inlet and outlet ventilation openings for passive airflow through the module interior. Ambient air enters at the bottom and flows around the canister and exits at the top. The vent locations shall minimize radiation streaming and optimize airflow. The vent design shall minimize the possibility of becoming blocked or exposed by relative sliding of adjacent HSM-HBs under the effects of a dynamic event such as a seismic event, or tornado wind and missiles.

- Protect vent openings with screens to prevent debris accumulation or animals from blocking or entering the HSM-HB.

- Provide the means to protect concrete surfaces closest to the canister from direct radiant heat to maintain general and local area temperatures in accordance with the requirements of Section 5.1.2.4.

- Provide the means to monitor concrete temperature through the use of thermocouples embedded in the area where maximum concrete temperatures are expected during normal operation.

5.1.2.4 HSM-HB Material Criteria

- All concrete used in the HSM-HB components shall be reinforced regardless of the functional role or need for structural strength or integrity (e.g. shielded door filling).

- Reinforcing steel shall conform to ASTM A615 or A706, Grade 60 unless otherwise specified and approved in the design drawings. All concrete reinforcement shall have a minimum specified yield strength of 60 ksi.

- Structural concrete used for the design shall have a 28 day specified compressive strength (f'c) of 5,000 psi.

- The concrete temperature limits criteria of Section A.4 Appendix A of ACI 349-97 [2.1.13] and those given in [2.4.16] shall apply.

- If concrete temperatures resulting from thermal analyses of the HSM-HB result in temperatures that exceed the limits of Appendix A of [2.1.13], or those given in page 3-5 of [2.4.16], concrete testing will be required to demonstrate that the elevated temperatures do not reduce concrete strength below the values assumed in the HSM-HB structural analyses. Analyses are to be performed assuming a 10% reduction in concrete and rebar strengths at temperature. This reduction in strength will be used as the acceptance criteria for any testing performed. Typical procedures for concrete testing are provided in Appendix A of [2.4.19].

- The nominal density of reinforced concrete shall be assumed to be 150 pcf.

- Fabrication of all miscellaneous steel framing, HSM-HB doors and embedments, heat shield, and screens shall conform to the applicable provisions of AISC Specification for Structural Steel Building [2.1.16] unless otherwise specified and approved in the design drawings. All welding shall be performed and welders qualified in accordance with the requirements of AWS D1.1 [2.1.17] or AWS D1.6 [2.1.16], as appropriate.

- No organic coatings on heat shields are permitted.

5.1.2.5 HSM-HB Geometry, Technical Specifications, and Weight Limits

- The HSM-HB configuration shall be based on optimizing the use of materials to achieve the stated dose limits in Section 12.0 with the flexibility to increase concrete section thickness to achieve more stringent criteria for site specific dose limitations. The design shall consider and qualify the enveloping geometry and weight.
- The HSM-HB cavity height, cavity width, elevation and cross sectional areas of the HSM-HB air inlet/outlet vents, the total outside height, length, and width of the HSM-HB may not be deviate by more than 8% of their nominal design values as approved by the NRC on the drawings in [2.4.12], Appendix P.
- The HSM-HB concrete shall be tested at elevated temperatures to verify that there are no significant signs of spalling or cracking and that the concrete compressive strength is greater than that assumed in the structural analysis. Tests shall be performed at or above the calculated concrete peak temperature and for a period no less than 40 hours (duration of HSM-HB blocked vent accident) , if the calculated concrete temperature for accident conditions exceeds 350°F. Typical procedures for concrete testing are provided in Appendix A of [2.4.19].
- The precast HSM-HB components shall be designed to be transported by barge, truck or rail.

5.1.3 CCNPP-FC TC Features and Considerations

As described in Section 3.0, the 32PHB DSC uses the modified CCNPP TC designated as CCNPP-FC TC for transfer operations. The CCNPP-FC TC has a top lid that allows cooling air, which is forced in at the bottom end of the cask to exit through cutouts around the perimeter of the TC top lid.

The CCNPP-FC transfer cask shall meet the criteria below:

- To improve thermal performance, the TC is to allow forced cooling air to enter through the ram access cover plate opening. The ram access cover plate is replaced by an adapter cone that mates the fan hose to the ram access opening.
- A spacer with wedge shaped protrusions installed at the cask bottom plate is used to duct the airflow to the perimeter of the TC/DSC annulus.
- Minimize pressure drop as the forced airflow is allowed to flow in the annulus between the DSC and the cask's inner shell.

6.0 ENVIRONMENTAL CONDITIONS

This section provides the generic environmental conditions to be used in generating the design basis loads for the new components used in NUHOMS® 32PHB system: the NUHOMS®32PHB DSC and the CCNPP-FC TC. The design basis loads for the transfer casks described in [2.4.14] are applicable to CCNPP-FC TC. The design basis loads for the HSM-HB module are the same as those described in the UFSAR [2.4.12], Appendix P for HSM-H. The loads considered are as follows:

- Dead Weight
- Wind and Tornado
- Snow and Ice
- Seismic
- Flood
- Forest Fire
- Thermal

6.1 Dead Load

Dead load is the weight of the structure and attachments including permanently installed equipment. For the CCNPP-FC TC analysis, the dead load shall be varied by + 5% if that produces the most adverse loading condition, regardless of the load combination factor applied.

The following deadweight loads shall be considered for the DSC:

1. The weight of the empty DSC (DW_1), hanging vertically by the DSC lifting fixture without the Top Shield Plug and Top Cover Plate in place, shall be considered. The DSC stresses for this condition shall not exceed ASME code allowables with a load factor of 1.5.

2. The weight of the DSC (DW_2), including the Top Shield Plug, loaded with fuel and filled with borated water (hydrostatic head), resting in the Transfer Cask (TC) cavity with annuls water in vertical orientation, shall be considered.

3. The weight of the dried DSC (DW_3), including the top shield plug and top cover plate, loaded with fuel resting horizontally in the Transfer Cask cavity or the HSM-HB, shall be considered.

6.2 Wind, Tornado, and Snow

There are no credible wind, tornado, or snow loads applied to the canister as the HSM-HB and CCNPP-FC TC provide the environmental protection.

The design basis loads related to wind, tornado, and snow are described in [2.4.14], Section 4.3 are applicable to CCNPP-FC TC. The design loads for HSM-HB are the same as those described in [2.4.12], Appendix P, Section P.2.2.1 for HSM-H.

6.3 Seismic

The seismic loads induced into DSC through the HSM-HB or TC shall be developed in accordance with NRC Regulatory Guides 1.6 and 1.61 ([2.3.3] and [2.3.4] with ground accelerations of 0.15g horizontal and 0.10g vertical, with 3% critical damping. In lieu of a site specific seismic analysis of the HSM-HB/DSC support structure and loaded DSC, the DSC assembly may be analyzed for the above seismic accelerations applied as equivalent static loads in accordance with Section 8.2.3.2, Paragraph A.ii, "DSC Seismic Stress Analysis", of the NUTECH Topical Report NUH-002 [2.4.1], If it is decided to perform a dynamic response spectrum analysis for seismic loads, a procedure consistent with NRC Regulatory Guide 1.92 [2.3.6] shall be used for combining the response values for individual modes.

The seismic loads described in [2.4.14] are applicable to CCNPP-FC TC. The seismic loads for HSM-HB are the same as those described in [2.4.12] for HSM-H and remain unchanged.

6.4 Flood

Flood loading is excluded by the ISFSI USAR and need not be considered in the design of the 32PHB DSC.

6.5 Fire Accident

A postulated fire accident shall be considered based on ISFSI USAR [2.4.5], Section 3.3.6. A maximum fuel spill of 100 gallons of diesel fuel, which is the maximum capacity of both fuel tanks within the tow vehicles, shall be considered for this evaluation.

6.6 Forest Fire

A postulated forest fire shall be considered based on ISFSI USAR [2.4.5]. The forest fire shall be assumed to occur at a distance of 130 feet from the nearest HSM-HB. The flame front is 200 feet long by 100 feet in height burning at an effective flame temperature of 1832°F for a period of 1 hour. The flame emissivity is 0.9. An average initial concrete temperature may be considered for this analysis based on off-normal ambient conditions described in Section 6.7.2.

6.7 Thermal Environmental Conditions

6.7.1 Fuel Handling Building Conditions

Based on CCNPP specification [2.4.2], Section 3.3, the maximum ambient temperature for all operations is 104°F. To account for the heat up of the Auxiliary Building during the loading operation, the loaded canister and CCNPP-FC TC will be analyzed for a normal (steady state) average ambient temperature of 100°F for operations which take place inside the Auxiliary Building, including vacuum drying, blowdown, and canister cavity water heat up. The maximum pool water temperature is 140°F. Maximum relative humidity is 100%.

6.7.2 ISFSI Site Conditions

Thermal loading for the CCNPP-FC TC and HSM-HB shall consider the full range of plausible natural weather temperatures and fluctuations and the heat dissipation from the stored canisters. As a minimum, the following conditions shall be used in the appropriate thermal analyses.

- Off-normal ambient temperature range of -8°F without insolation to 104°F with full insolation. A solar heat flux of 127 Btu/hr-ft^2 on the outer surface of the HSM-HB shall be assumed to occur concurrently with the 104°F ambient.

- Normal ambient temperature range of -8°F without insolation to 104°F with full insolation. A solar heat flux of 82 Btu/hr-ft^2 on the outer surface of the HSM-HB shall be assumed to occur concurrently with the 104°F ambient. The design lifetime average ambient temperature is 70°F based on ISFSI USAR [2.4.5], Section 8.1.3.

- Relative humidity of 100%.

- Blockage of the inlet or outlet cooling vents at the extreme ambient temperatures of -8°F and 104°F. A solar heat flux of 127 Btu/hr-ft^2 on the outer surface of the HSM-HB shall be assumed to occur concurrently with the 104°F ambient. The maximum time of 36 hours shall be considered for the blocked vent transient with the maximum heat load for the design basis fuel.

6.8 Other Natural Phenomena

Other natural phenomena, such as lightning, tsunamis, and hurricanes are described in ISFSI USAR [2.4.5]. The effects of these site specific phenomena are generally bounded by other events and are excluded from the scope of this criteria document.

7.0 OPERATIONAL CONDITIONS

7.1 HSM-HB

The design criteria for the HSM-HB are the same as those documented in the Design Criteria Specification for the NUHOMS® 32PTH1 System, Reference [2.4.14] for HSM-H except for the items defined in Section 7.1.1 below.

7.1.1 Normal and Off-Normal Operational Handling Loads

Normal operation handling loads on the HSM-HB are the result of canister transfer operations. Normal operation assumes the canister is sliding over the support structure due to a hydraulic ram force of up to 23,750 lbs applied at the grapple ring [2.4.4].

The design basis off-normal operating load is due to a hydraulic ram force of 80,000 lbs applied at the grapple ring.

The axial load should be transferred to the HSM-HB support structure. In addition, half the loaded weight of the canister should be applied as a concentrated load midspan of the HSM-HB support structure.

The design loads for HSM-HB structure are listed in Table 8-11. The design loads are bounding for the handling forces from the hydraulic ram.

7.2 32PHB Canister

The canister loads are developed for normal, off-normal, and accident conditions. The following provides a general discussion of the operational loads. Detailed criteria are provided in Section 8.0.

7.2.1 Normal Operational Loads

Normal operational loads are defined as the dead loads, pressure and temperature conditions that result from normal storage and transportation conditions. Normal operational handling loads result from the transfer of a canister from the fuel building to the HSM-HB using the CCNPP-FC on-site transfer cask. The loads considered shall include those transferred from cask to canister and the insertion/withdrawal loads during transfer in/out of an HSM-HB. These loads are described in detail in Section 8.0.

7.2.2 Off-Normal Operational Loads

Off-normal operation handling loads are the result of a canister getting stuck or jammed during transfer into or out of the HSM-HB. These loads are described in detail in Section 8.0.

7.2.3 Accident Operational Loads

These loads are the result of a loaded 32PHB canister drop event associated with the CCNPP-FC transfer cask events. For transfer operations the canister is protected from the environment and operational loads by the TC and the canister provides the confinement boundary for the fuel. The cask/canister drop events are arbitrarily defined with no mechanistic basis for the loads.

7.3 CCNPP-FC Transfer Cask

To limit the off-gas pressure within the neutron shield panel and limit the hydrogen loss of the NS-3 neutron shield to less than 10%, a maximum bulk temperature of 280°F is considered for the NS-3 neutron shield. The set point of the TC neutron shield safety relief valve is 95 psig according to [2.4.5], Section 8.1.3.3.

The structural design criteria for the CCNPP-FC TC are described in Section 9.0.

7.4 Load Combinations

Individual load conditions are listed in Table 7-1. Summaries of the load combinations are shown in Table 7-2 and Table 7-3 for DSC shell and basket assemblies, respectively. These tables include the applicable ASME service level for each combination. Analyses for the on-site "accident" conditions may use either elastic or elastic-plastic analyses with the appropriate allowables from Table 8-7 and/or Table 8-8.

Table 7-1
DSC Structural Loading Conditions

Item No.	Applicable Individual Loads	Condition	Load Value
1	Dead Weight	---	---
2	Temperatures	Hot ambient of 104°F	---
3		Cold ambient –8° F	---
4		Transfer Accident	---
5		HSM-HB Accident	---
6	Internal Pressure	Normal	15 psig
7		Off-Normal	20 psig
8		Accident	100 psig
9	Hydrostatic Pressure (External)	---	---
10	Handling Loads	Normal	See Table 8-11
11		Off-Normal	
12		Accident	
13	Transfer Loads	Normal	Dead load ± 1g vertical
14			Dead load ± 1g axial
15			Dead load ± 1g longitudinal
16			Dead load ± ½g all directions
17		Accident	Top End Drop, 75g
18			Bottom End Drop, 75g
19			Side Drop, 75g
20	Seismic	0.36g Axial + 0.41g Transverse + 0.25g Vertical + 1.0g Down (DW)	0.36g Axial + 0.41g Transverse + 1.25g Vertical
21		Stability	0.41g Transverse + 0.25g Vertical
22	Test Pressure	Normal	16.5 psig
23	Blow-Down Pressure	Normal	20 psig

Table 7-2
Summary of 32PHB DSC Shell Load Combinations

Load Combinations Case		Normal Operating Conditions							Off-Normal Conditions						Emergency Conditions / Accident Conditions						
		1	2	3	4	5	6	7	1	2	3	4	5	6	1	2	3	4	5	6	7
Dead Weight	Vertical, DSC Empty	X																			
	Vertical, DSC w/ and w/o Water		X																		
	Horizontal, DSC w/Fuel			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Thermal	Inside HSM: 70°F (ambient)				X										X						
	Inside Cask: 70°F (ambient)		X	X		X	X		X									X		X	
	Inside HSM: 104°F (ambient)										X		X			X					
	Inside Cask: 104°F (ambient)									X		X		X							
	Inside Cask: Accident																X		X		
	Inside HSM: Accident (vent block)																				X
Internal Pressure	Normal Pressure			X					X						X	X				X	
	Off-Normal / Blowdown				X		X			X	X	X	X	X							
	Accident																		X		X
External Pressure	Hydrostatic		X																		
Handling Loads	Normal			X	X																
	Off-Normal								X	X	X										
Transfer Loads	Normal					X	X						X	X							
	Accident (Drop)																	X		X	
Seismic															X						
ASME Code Service Level		A	A	A	A	A	A	A	B	B	B	B	B	B	C	C	D	D	D	D	D

Table 7-3
Summary of 32PHB Basket Load Combinations

Load Combinations Case		Normal Operating Conditions			Off-Normal Conditions		Emergency Conditions / Accident Conditions		
		1	2 [2]	3 [3]	1	2	1	2	3
Dead Weight	Vertical	X							
	Horizontal		X	X	X	X	X	X	X
Thermal	Inside HSM: 70°F (ambient)		X						
	Inside Cask: 70°F (ambient)			X					
	Inside HSM: 104°F (ambient)				X		X		
	Inside Cask: 104°F (ambient)	X				X			
	Inside HSM: Accident (vent block)							X	
Transfer Loads	Normal			X		X			
	Accident [1]								X
Seismic							X		
ASME Code Service Level		A	A	A	B	B	C	D	D

Notes:
[1] Side Drop orientations of 0°, 45°, 60°, and 180°, and End Drop should be considered for accident transfer load analysis.
[2] This load case is bounded by Off-Normal Condition load case 1.
[3] This load case is bounded by Off-Normal Condition load case 2.

8.0 DSC STRUCTURAL DESIGN REQUIREMENTS

8.1 NUHOMS® 32PHB DSC Structural Design Criteria

The 32PHB DSC is designed to meet the criteria of ASME Code Subsection NB. Service Level A and B allowables are used to for all normal operating and off-normal loadings. Service Level C and D allowables are used for load combinations that include postulated accident loadings.

Material Properties used in the 32PHB analysis are summarized in Table 8-1 through Table 8-6. The material properties for lead and air are listed in Table 9-7 through Table 9-9.

8.1.1 NUHOMS® 32PHB DSC Shell Stress Limits

The stress limits for the DSC shell are taken from the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-3200 for Level A through D Service Limits [2.1.2]. In accordance with NB-3225, Appendix F is used for accident condition loads (Level D).

The stress due to each load shall be identified as to the type of stress induced, e.g. membrane, bending, etc., and the classification of stress, e.g. primary, secondary, etc.

Stress limits for Level A through D service loading conditions are summarized in Table 8-7. Local yielding is permitted at the point of contact where Level D load is applied. If elastic stress limits cannot be met, the plastic system analysis approach and acceptance criteria of Appendix F of Section III shall be used.

The allowable stress intensity value, S_m, as defined by the Code, is to be based on the calculated (or a bounding) temperature for each service load condition.

The canister closure welds shall be designed in accordance with the guidance of ISG-15 [2.3.23].

Structural stability of the 32PHB DSC shell assembly is evaluated for those load conditions in which the DSC is under external pressure and/or axial compression. The stability criteria for Level A load conditions are from ASME Section III, NB-3133.3 and NB-3133.6 [2.1.2]. For the accident drop the shell assembly stability load may be evaluated based on non-linear, large displacement analysis model using ANSYS.

8.1.2 NUHOMS® 32PHB Canister Basket Stress Limits

The basket fuel compartment tube wall thickness is established to meet heat transfer, nuclear criticality, and structural requirements. The basket structure must provide sufficient rigidity to maintain a subcritical configuration under the applied loads.

The stress analyses of the basket do not take credit for the poison plates except for through thickness compression. However, the poison plate strength may be considered when determining secondary stresses in the stainless steel.

The basis for the stainless steel fuel compartment section stress allowables is the ASME Code, Section III, Subsection NG [2.1.2]. Stress limits for Level A through D service loading conditions are summarized in Table 8-8.

Alternatively, and in accordance with NG-3222 and Note 9 to Figure NG-3221-1, the Limit Analysis provisions of NG-3228 may be used for Level A Service Limits.

The basket shall be evaluated under Level D Service loadings in accordance with the Level D Service limits for components in Appendix F of Section III of the Code. The hypothetical impact accidents are evaluated as short duration Level D conditions. For elastic quasistatic analysis, the primary membrane stress is limited to the smaller of $2.4S_m$ or $0.7S_u$ and membrane plus bending stress intensities are limited to the lesser of 3.6 S_m or S_u. The maximum primary shear stress is limited to 0.42 S_u. When evaluating the results from the non-linear elastic-plastic analysis for the accident conditions, the general primary membrane stress intensity, P_m, shall not exceed the greater of $0.7S_u$ or $S_y + 1/3\ (S_u - S_y)$ and the maximum stress intensity at any location (P_l or $P_l + P_b$) shall not exceed 0.9 S_u.

Finite element non-linear buckling analysis or hand calculations should be used in calculating the critical loads for buckling of the shell and basket. Reasonable safety factors for the allowable buckling loads should be provided to take into account material and geometrical imperfections.

The solid aluminum transition rails perform their function by remaining in place. The loads on these rails are primarily bearing. Therefore, for deadweight and handling conditions, stress in the solid aluminum bodies will be compared to the allowable bearing stress, S_y, from NG-3227.1(a). For accident condition loads (i.e. postulated drops), the rail bodies support the fuel compartment tube structure such that stresses and displacements in the compartment tube structure are acceptable. Since the solid aluminum rails are entrapped between the fuel compartment tube structure and the DSC shell, no additional checks of the aluminum are required for accident loading. Qualification of the fuel compartment tube structure demonstrates that the rails perform their intended function.

The fuel to be stored in the 32PHB DSC is described in Section 4.0. Under side loads (e.g., horizontal dead weight, side drops, etc.), the fuel is assumed to have no structural capacity. That is, the fuel load is applied to the basket fuel compartments as a pressure load which varies with axial location of the fuel and components along the 32PHB DSC cavity.

The load imposed by the fuel on the basket fuel compartments is a function of the linear weight distribution (lb/in) of the fuel assemblies. That is, the load in the active fuel region may be larger than the load at the ends of the fuel assembly. This linear weight distribution shall be determined using the weight and geometry data given in Section 4.0. Alternatively, a conservative bounding weight per linear inch may be used.

The criteria for the fusion welds in the basket shall be by test. These are resistance (fusion) welds, and are not addressed explicitly in NG-3352-1. This is a Code exception to NG-3352-1. Fusion welds between the stainless steel support bars and the stainless steel fuel compartments shall be qualified by testing. The required minimum tested capacity of the weld connection shall be based on the margin of safety (test to design) of 1.43 (see Appendix F, Section 1342(c) of ASME code [2.1.4]), corrected for the temperature difference between testing and basket operating conditions and the maximum weld load at any weld location in the basket.

The stress and load limits for the basket are summarized in Table 8-8.

8.2 Fuel Assembly Evaluations

The fuel assemblies are evaluated to demonstrate fuel cladding integrity under normal, off-normal, accident, loading, and unloading conditions. The evaluations may address individual assemblies or may be based on a single bounding assembly. The evaluations may use hand calculations or computer analysis models. Equivalent static or dynamic analysis may be used. In accordance with ISG-12 the weight of the pellets is included in the analysis. However, no credit for the pellets is to be taken in the development of the section properties of the cladding (cross sectional area, moment of inertia). Cladding material properties are to be consistent with high burn up fuel and should include a thickness reduction due to oxidation.

The analysis should use irradiated material properties and strain rate effects as per References [2.4.25] and [2.4.20]. The acceptance criterion is per ISG-12, i.e., cladding integrity is assured if the cladding stress remains below yield strength. Alternatively the methodology and criteria from Reference [2.4.23] may be applied. Material properties may be based on Reference [2.4.24].

8.3 Weld stresses

The 32PHB DSC closure welds are in accordance with the guidance of ISG-15 [2.3.23]. These include the joints between the top cover plate and top shield plug assembly to the shell and the vent and siphon block welds in the top shield plug asembly. These welds are partial penetration welds subject to PT examination. Other DSC shell assembly welds are in accordance with NB-4243 and NB-5230.

8.4 Canister Loads Descriptions

A summary of the load and load combinations used for the 32PHB design was listed in Table 7-2. This section provides a summary description of the individual loads requiring evaluation for 32PHB DSC design.

8.4.1 Deadweight

Deadweight loads include the self-weight of the 32PHB DSC (including basket assembly), and stored fuel.

8.4.2 Internal Pressure

Pressure loads for the 32PHB DSC are based on conditions defined by NUREG-1536, Section 4.0.V.5.c and NCA-2142.1(a).

For storage considerations, it shall be assumed that 1% of the fuel rods are failed for normal conditions, up to 10% of the fuel rods are failed for off normal conditions, and 100% of the fuel rods will have failed following a design basis accident. Since no drop is postulated for the HSM-HB blocked vent accident condition, it should be assumed that only 10% of the fuel rods are failed for this accident condition.

The total amount of fission and filled gases that can be released from each fuel rod is 97.9186 in^3 at STP (68°F and 1 atm) per fuel rod for 62 GWD/MTU burnup.

Required pressures for structural analysis for Normal, Off-Normal, and Accident conditions are listed in Table 8-9. The helium backfill pressure of the DSC is defined as 2.5±1.0 psig.

8.4.3 Thermal

For the 32PHB DSC analyses, temperature profiles and maximum component temperatures are based on thermal analyses, which consider the environmental conditions listed in Table 8-10 with a maximum heat load of 29.6 kW per DSC and heat load zoning configuration shown in Figure 4-1.

The component temperatures shall be used in determining the allowable stresses for each condition. Maximum thermal gradients are to be considered for determining thermal stresses.

8.4.4 Seismic

As described in Section 6.3, the 32PHB seismic criteria consists of the Regulatory Guide 1.60 Response Spectra, anchored to 0.15g and 0.10g horizontal and vertical peak ground accelerations, respectively. The 32PHB DSC shall be analyzed for seismic accelerations considering the dynamic response of the HSM-HB, as applicable. In addition, the 32PHB DSC shall be analyzed considering the possibility of loading only a single rail. The seismic loading is considered by simultaneously applying the seismic accelerations as equivalent static loads in each orthogonal direction. The results for each direction may be combined by SRSS. For a seismic event occurring during transfer of a 32PHB DSC, the transfer loads specified in Section 8.4.5.1 provide assurance for the integrity of the 32PHB DSC components.

8.4.5 Handling

There are two categories of "handling" loads: (1) inertial loads associated with moving the 32PHB DSC and (2) the loads associated with inserting the 32PHB DSC into (and retrieving the 32PHB DSC from) the HSM-HB.

8.4.5.1 Transfer Handling

Transfer handling loads are inertial loads on the loaded 32PHB DSC resulting from on-site handling and transportation between the fuel handling/loading area and the HSM-HB. The four independent load cases to be considered in the design are:

± 1.0g Axial
± 1.0g Transverse
± 1.0g Vertical
± 0.5g Axial ± 0.5g Transverse ± 0.5g Vertical (cask horizontal)

8.4.5.2 HSM-HB Insertion/Retrieval

To load the 32PHB DSC into the HSM-HB, the 32PHB DSC is pushed out of the transfer cask using a hydraulic ram. The load is applied to the center of the 32PHB DSC outer bottom cover at the center of the grapple ring assembly.

To unload the HSM-HB, the 32PHB DSC is pulled using grapples which fit into the grapple ring on the outer bottom cover. The allowable hydraulic ram forces and the design loads considered for Insertion/Retrieval loads are listed in Table 8-11. It should be noted that the design loads are bounding for the hydraulic ram forces.

8.4.6 Drop Loads

Postulated on-site transfer drop loads apply to all parts of the 32PHB DSC. The following loads are to be considered for on-site transfer drops.

Equivalent static deceleration:
 75g vertical end drop
 75g horizontal side drop
 25g corner drop with slap down
 (corresponds to an 80" drop height)
 Structural damping during drop: 10%

The above loads are taken from USAR [2.4.5] for NUHOMS® 24P and 32P designs. No evaluation is required for corner drop since the stresses are bounded by the vertical drop stresses as shown in USAR [2.4.5].

8.4.6.1 Tornado Wind and Missile Loads

The 32PHB DSC is protected from tornado wind and missile loads by the transfer cask or the HSM-HB. Therefore, no evaluation is required for these loads.

8.4.7 Flood Loads

Flood loading is excluded by CCNPP Specification 2.4.4 and need not be considered in the design of the DSC.

Table 8-1
Material Properties – SA-240/SA-479 Type 304 (DSC)

Nominal Composition: 18Cr-8Ni

Temp (°F)	E (10^3 ksi)	S_m (ksi)	S_y (ksi)	S_u (ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})	ρ (lb/in^3)	k (Btu/hr-ft-°F)	α (ft^2/hr)
-20		20.0	30.0	75.0					
70	28.3				8.5	8.5		8.6	0.151
100		20.0	30.0	75.0	8.7	8.6		8.7	0.152
150			26.7		9.0	8.8			
200	27.6	20.0	25.0	71.0	9.3	8.9		9.3	0.156
250			23.6		9.6	9.1			
300	27.0	20.0	22.4	66.2	9.8	9.2		9.8	0.160
350					10.0	9.3			
400	26.5	18.7	20.7	64.0	10.2	9.5		10.4	0.165
450					10.3	9.6			
500	25.8	17.5	19.4	63.4	10.4	9.7	0.290	10.9	0.170
550					10.6	9.8			
600	25.3	16.4	18.4	63.4	10.7	9.8		11.3	0.174
650		16.2	18.0	63.4	10.8	9.9			
700	24.8	16.0	17.6	63.4	10.9	10.0		11.8	0.179
750		15.6	17.2	63.3	11.0	10.0			
800	24.1	15.2	16.9	62.8	11.1	10.1		12.2	0.184
850			16.5	62.0	11.1	10.1			
900	23.5		16.2	60.8	11.2	10.2		12.7	0.189
950			15.9	59.3	11.3	10.3			
1000	22.8		15.5	57.4	11.4	10.3		13.2	0.194
SA-240 304	Table TM-1 pg 606.1 group G	Table 2A pg 328 line 12	Table Y-1 pg 520 line 9	Table U pg 453.3 line 9	Table TE-1 pg 583 group 3		Perry Table 23-5	Calculated based on Table TCD pg 594 group J	
SA-479 304	Table TM-1 pg 606.1 group G	Table 2A pg 328 line 26	Table Y-1 pg 520 line 25	Table U pg 453.3 line 25					

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Table 8-2
Material Properties – Aluminum 6061 (DSC)

SB-209 A96061 T651 (.25" - 4.0") or T6 (.051" - .249")

Temp (°F)	E (10^3 ksi)	S_m (ksi)	S_y (ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})	ρ (lb/in³)	k (Btu/hr-ft-°F)	α (ft²/hr)
-20		14.0	35.0					
70	10.0			12.1	12.1		96.1	2.66
100		14.0	35.0	12.5	12.4		96.9	2.66
150		14.0	34.6	12.9	12.7		98.0	2.65
200	9.6	14.0	33.7	13.3	13.0		99.0	2.65
250		13.4	32.4	13.6	13.1	0.098	99.8	2.64
300	9.2	11.3	27.4	13.9	13.3		100.6	2.63
350			20.0	14.2	13.4		101.3	2.62
400	8.7		13.3	14.6	13.6		101.9	2.62
450				14.8	13.8			
500	8.1			14.9	13.9			
550				15.2	14.1			
600				15.3	14.2			
	Table TM-2 pg 607 A96061	Table 2A pg 366 lines 3/4	Table Y-1 pg 552 lines 23/24	Table TE-2 pg 585		Table NF-2 pg 611,612	Calculated based on Table TCD pg 604, group A96061	

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Table 8-3
Analysis Properties for Aluminum Transition Rails (DSC) [2.4.26]

6061-O Aluminum (Annealed)

Temperature (°F)	S_u, 6061-O (ksi)	S_y, 6061-O (ksi)	E (10^3 ksi)
75	18.0	8.0	9.9
212	18.0	8.0	9.5
300	15.0	8.0	9.1
350	12.0	8.0	8.9
400	10.0	7.5	8.6
450	8.5	6.0	8.3
500	7.0	5.5	7.9
600	5.0	4.2	6.8
700	3.6	3.0	5.5
800	2.8	2.2	---
900	2.2	1.6	---
1000	1.6	1.2	---

Table 8-4
Material Properties – Aluminum 1100 (DSC)

Aluminum Alloy A91100

Temp (°F)	E (10^3 ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})	ρ (lb/in^3)	k (Btu/hr-ft-°F)	α (ft^2/hr)
-20						
70	10.0	12.1	12.1		133.1	3.67
100		12.5	12.4		131.8	3.61
150		12.9	12.7		130.0	3.50
200	9.6	13.3	13.0		128.5	3.42
250		13.6	13.1		127.3	3.35
300	9.2	13.9	13.3	0.098	126.2	3.28
350		14.2	13.4		125.3	3.23
400	8.7	14.6	13.6		124.5	3.17
450		14.8	13.8			
500	8.1	14.9	13.9			
550		15.2	14.1			
600		15.3	14.2			
	Table TM-2 pg 607 A91100	Table TE-2 pg 585		Table NF-2 pg 611,612	Calculated based on Table TCD pg 604, group A91100	

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Table 8-5
Material Properties – Helium (DSC)

Temperature (K)	Thermal conductivity (W/m-K)	Temperature (°F)	Thermal conductivity (Btu/hr-in-°F)
300	0.1499	80	0.0072
400	0.1795	260	0.0086
500	0.2115	440	0.0102
600	0.2466	620	0.0119
800	0.3073	980	0.0148
1000	0.3622	1340	0.0174
1050	0.3757	1430	0.0181

The above data are calculated base on the following polynomial function from: Rohsenow, W.M., "Handbook of Heat Transfer", 3rd Edition, McGraw-Hill Handbooks.

$k = \sum C_i\, T_i$ for conductivity in (W/m-K) and T in (K)

For 300 < T < 500 K		for 500< T < 1050 K	
C0	-7.761491E-03	C0	-9.0656E-02
C1	8.66192033E-04	C1	9.37593087E-04
C2	-1.5559338E-06	C2	-9.13347535E-07
C3	1.40150565E-09	C3	5.55037072E-10
C4	0.0E+00	C4	-1.26457196E-13

Table 8-6
Material Properties – Nitrogen

Temperature (K)	Thermal conductivity (W/m-K)	Temperature (°F)	Thermal conductivity (Btu/hr-in-°F)
366	0.0304	200	1.466E-03
422	0.0304	300	1.636E-03
478	0.0373	400	1.797E-03
533	0.0405	500	1.950E-03
588	0.0435	600	2.096E-03
644	0.0464	700	2.236E-03
700	0.0493	800	2.372E-03
755	0.0520	900	2.503E-03
811	0.0546	1000	2.630E-03
866	0.0572	1100	2.753E-03

The above data are calculated base on the following polynomial function from: Rohsenow, W.M., "Handbook of Heat Transfer", 3rd Edition, McGraw-Hill Handbooks.

$k = \sum C_i\, T_i$ for conductivity in (W/m-K) and T in (K)

For 250 < T < 1050 K			
C0	-1.52318E-03	C3	1.15568E-10
C1	1.18880E-04	C4	-6.36537E-14
C2	-1.20928E-07		

Table 8-7
Summary of Stress Criteria for Subsection NB Pressure Boundary Components
(e.g., Shells and Cover Plates)
(continued)

Service Level	Stress Category	References	Notes
Design [NB-3221]	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b \leq 1.5S_m$ $F_p \leq 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ External Pressure: NB-3133	NB-3221.1, NB-3221.2, NB-3221.3, NB-3227.1 and NB-3227.4	
Level A [NB-3222]	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b + Q \leq 3.0S_m$ $F_p \leq 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ External Pressure: NB-3133	NB-3222, NB-3227.1, & NB-3227.4	Notes 1 & 2
Level B [NB-3223]	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b + Q \leq 3.0S_m$ $F_p \leq 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ External Pressure: NB-3133	NB-3223, NB-3227.1, & NB-3227.4	Notes 1 & 3
Level C [NB-3224]	$P_m \leq \max(1.2S_m, 1.0S_y)$ $P_L \leq \max(1.8S_m, 1.5S_y)$ $P_m\ (or\ P_L) + P_b \leq \max(1.8S_m, 1.5S_y)$ $P_m\ (or\ P_L) + P_b + Q \leq$ note 4 $F_p \leq 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ External Pressure: 1.20*NB-3133	NB-3224, NB-3227.1 & NB-3227.4	

Table 8-7
Summary of Stress Criteria for Subsection NB Pressure Boundary Components
(concluded)

Service Level	Stress Category	References	Notes
Carbon Steel Components (e.g., shield plugs)			
Level D Elastic Analysis [NB-3225, App. F]	$P_m \le 0.7S_u$ $P_m\ (or\ P_L) + P_b \le 1.0S_u$ $P_m + P_b + Q \le note\ 4$ $F_p \le note\ 5$ External Pressure = 1.5 * NB-3133	NB-3225, F-1331.1 & F-1331.5(b)	Note 6
Level D Plastic Analysis [NB-3225, App. F]	$P_m \le 0.7S_u$ $P_m\ (or\ P_L) + P_b \le 0.9S_u$ $P_m + P_b + Q \le note\ 4$ $F_p \le note\ 5$ External Pressure = 1.5 * NB-3133	NB-3225, F-1341.2 & F-1331.5(b)	Note 6
Austenitic Steel Components (e.g., Shell)			
Level D Elastic Analysis [NB-3225, App. F]	$P_m \le \min(2.4S_m, 0.7S_u)$ $P_m\ (or\ P_L) + P_b \le \min(3.6S_m, 1.0S_u)$ $P_m + P_b + Q \le note\ 4$ $F_p \le note\ 5$ External Pressure = 1.5 * NB-3133	NB-3225, F-1331.1 & F-1331.5(b)	Note 7
Level D Plastic Analysis [NB-3225, App. F]	$P_m \le \max(0.7S_u, S_y + (S_u - S_y)/3)$ $P_m\ (or\ P_L) + P_b \le 0.9S_u$ $P_m + P_b + Q \le note\ 4$ $F_p \le note\ 5$ External Pressure = 1.5 * NB-3133	NB-3225, F-1341.2 & F-1331.5(b)	Note 7

Notes:

(1) This limit may be exceeded provided the criteria of NB-3228.5 are satisfied.

(2) There are no specific limits on primary stresses for Level A events. However, the stresses due to primary loads during normal service must be computed and combined with the effects of other loadings in satisfying other limits. See NB-3222.1.

(3) The 10% increase in allowables from NB-3223(a) may be applicable for load combinations for which the pressure exceeds the design pressure.

(4) Evaluation of secondary stresses not required for Level C and D events.

(5) Evaluation of bearing stresses not required for Level D events.

(6) Criteria listed are for carbon steel components (e.g., shield plugs).

(7) Criteria listed are for austenitic parts including shells, cover plates, and the grapple assembly.

Table 8-8
Summary of Stress Criteria for Subsection NG Components (Austenitic)
(e.g., Fuel Compartment, Transition Rails)

Service Level	Stress Category (5)	References	Notes
Design [NG-3221]	$P_m \leq 1.0S_m$ $P_m + P_b \leq 1.5S_m$	NG-3221.1 NG-3221.2	
Level A [NG-3222]	$P_m \leq 1.0S_m$ $P_m + P_b \leq 1.5S_m$ $P_m + P_b + Q \leq 3.0S_m$ (*note* 4)	NG-3222.1, NG-3221.1 NG-3222.1, NG-3221.2 NG-3222.2	Note 6
Level B [NG-3223][1]	$P_m \leq 1.0S_m$ $P_m + P_b \leq 1.5S_m$ $P_m + P_b + Q \leq 3.0S_m$ (*note* 4)	NG-3223(a), NG-3222.1, NG-3221.1 NG-3223(a) NG-3222.1, NG-3221.2 NG-3223(a), NG-3222.2	Note 1
Level C Elastic Analysis [NG-3224]	$P_m \leq 1.5S_m$ $P_m + P_b \leq 2.25S_m$ $P_m + P_b + Q \leq$ *note* 2	NG-3224.1(a)(1) NG-3224.1(a)(2) Figure NG-3224-1	Notes 2 & 3
Level D Elastic Analysis [NG-3225, App. F]	$P_m \leq \min(2.4S_m, 0.7S_u)$ $P_m + P_b \leq \min(3.6S_m, 1.0S_u)$ $P_m + P_b + Q \leq$ *note* 2	NG-3225, F-1440, F-1331.1(a) NG-3225, F-1440, F-1331.1(c)	
Level D Plastic Analysis [NG-3225, App. F]	$P_m \leq \max[0.7S_u, S_y + 1/3(S_u - S_y)]$ $P_m + P_b \leq 0.9S_u$ $P_m + P_b + Q \leq$ note 2	NG-3225, F-1440, F-1341.1(a) NG-3225, F-1440, F-1341.2(c)	

Notes:
(1) There are no pressure loads on the basket, therefore the 10% increase permitted by NG-3223(a) for pressures exceeding the design pressure are not included.
(2) Evaluation of secondary stresses not required for Level C and D events.
(3) Criteria listed are for elastic analyses, other analysis methods permitted by NG-3224.1 are acceptable if performed in accordance with the appropriate paragraph of NG-3224.1.
(4) This limit may be exceeded provided the requirements of NG-3228.3 are satisfied, see NG-3222.2 and NG-3228.3.
(5) As appropriate, the special stress limits of NG-3227 should be applied.
(6) In accordance with NG-3222 and Note 9 of Figure NG-3221-1, the Limit Analysis provisions of NG-3228 may be used.

Table 8-9
32PHB DSC Pressure Loads

Operating Condition	Internal Pressure	ASME Service Level
"Normal Pressure" (1% rods ruptured)	15 psig	A
"Blow Down"	20 psig	A
"Off-Normal" Pressure (10% rods ruptured)	20 psig	B
"Accident" Pressure (100% rods ruptured during Transfer Accidents) (10% rods ruptured for blocked vent accident in HSM-HB)	100 psig	D

Note:

(1) Conditions (percentage of rods damaged) are from Section 4.0.V.5.c of NUREG-1536 [2.3.19].

Table 8-10
Thermal Conditions for 32PHB DSC Analyses

Operating Conditions	32PHB DSC Location	Minimum Ambient Temperature	Maximum Ambient Temperature	Solar Heat Flux	Reference
Normal	Transfer Cask (Fuel Building)	[3]	[3]	N/A	[2.4.15]
	Transfer Cask	-8°F	104°F	82 Btu/hr-ft^2	[2.4.4]
	HSM	-8°F	104°F	82 Btu/hr-ft^2	[2.4.4]
Off-Normal	Transfer Cask (Fuel Building)	[3]	[3]	N/A	---
	Transfer Cask	-8°F	104°F	127 Btu/hr-ft^2	[2.4.4]
	HSM-HB	-8°F	104°F	127 Btu/hr-ft^2	[2.4.4]
Accident	Transfer Cask (Loss of forced air)	n/a	104°F	127 Btu/hr-ft^2	[2.4.4]
	Transfer Cask (Fire Accident) [1]	n/a	104°F	127 Btu/hr-ft^2	[2.4.4]
	HSM-HB (Blocked inlet <u>or</u> outlet vents) [2]	-8°F	104°F	127 Btu/hr-ft^2	[2.4.4]

Notes:

(1) The transfer cask fire accident bounds the HSM-HB fire case.
(2) 10% rod rupture is considered for this blocked vent accident condition for DSC internal pressure calculation.
(3) An average ambient temperature of 100°F should be considered within Fuel (Auxiliary) Building

Table 8-11
Handling Loads

Operating Condition	Hydraulic Ram Forces (lbs)	HSM-HB Design Loads (lbs)	Transfer Cask Design Loads (lbs)	DSC Design Loads (lbs)	ASME Service Level
Normal	23,750	80,000 lbs for insertion 60,000 lbs for retrieval	23,750 lb	60,000 lb	A
Off-Normal	80,000	80,000 lbs for insertion and retrieval	95,000 lb	95,000 lb	B

Notes:
(1) The design loads listed in this table ensure that the hydraulic ram forces are bounded conservatively.

9.0 ONSITE TRANSFER CASK STRUCTURAL DESIGN REQUIREMENTS

9.1 Structural Design Criteria

The CCNPP-FC TC is designed to meet the criteria of ASME Code, 1992, Subsection NC for Class 2 components. Service Level A and B allowables are used to for all normal operating and off-normal loadings. Service Level C and D allowables are used for load combinations that include postulated accidents loadings.

Cask upper trunnions shall be evaluated for the 32PHB payload in accordance with ANSI N14.6 [2.1.8]. The local shell stresses at the trunnion locations may be analyzed per Welding Research Council [2.4.28]. Limit analysis specified in Appendix F of the ASME Code, Section III (F.1341.3) can also be used for structural evaluation of the cask for level D events.

The allowable stress criteria for the TC and the TC bolts are summarized in Table 9-10 and Table 9-11, respectively

9.2 Loads and Load Combinations

A summary of the load and load combinations used for the 32PHB design was listed in Table 7-2. This section provides a summary description of the individual loads requiring evaluation for the CCNPP-FC TC.

9.2.1 Deadweight

Deadweight loads shall include the self-weight of the transfer cask and the payload of the 32PHB DSC.

9.2.2 Internal Pressure

Since the 32PHB DSC provides pressure boundary, this load is not applicable for CCNPP-FC transfer cask.

9.2.3 Thermal

The thermal load for the CCNPP-FC TC is 29.6 kW. For the structural analyses, temperature profiles and maximum component temperatures are based on thermal loads listed in Table 8-10, which consider the environmental conditions described in Section 6.0.

The maximum component temperatures shall be considered in determining the allowable stresses for each condition. Maximum thermal gradients are to be considered for determining thermal stresses.

9.2.4 Seismic

The seismic design criteria consists of a maximum horizontal component ground acceleration of 0.15g and maximum vertical component of 0.10g as described in Section 3.2.5.3 of the USAR [2.4.5].

The seismic loads during transfer from the CCNPP Auxiliary Building to the HSM-HB site shall be developed in accordance with NRC Regulatory Guides 1.60 and 1.61 with accelerations of 0.15g horizontal and 0.10g vertical, with 3% critical damping. In lieu of a site specific seismic analysis, the DSC may be analyzed for the above seismic accelerations applied as equivalent static loads in accordance with Section 8.2.3.2, Paragraph A.ii, "DSC Seismic Stress Analysis", of the NUTECH Topical Report NUH-002 [2.4.1]. If a dynamic response spectrum analysis for seismic loads is performed, a procedure consistent with NRC Regulatory Guide 1.92 shall be used for combing the response values for individual modes.

9.2.5 Handling

Handling loads for CCNPP-FC TC are summarized in Table 8-11.

9.2.6 Drop Loads

The accident drop loads, which result from a postulated drop of TC loaded with 32PHB DSC shall be considered. The following drops are to be considered for on-site transfer drops.

Equivalent static deceleration:

75g vertical end drop
75g horizontal side drop
25g corner drop with slap down
(corresponds to an 80" drop height)
Structural damping during drop: 10%

The above loads are taken from USAR [2.4.5] for NUHOMS® 24P and 32P designs. No evaluation is required for corner drop since the stresses are bounded by the vertical drop stresses as shown in USAR [2.4.5].

9.2.7 Tornado Wind and Missile Loads

Tornado wind and missile loads for the HSM are used. Drop loads are normally bounding.

9.2.8 Flood Loads

Flood loading is excluded by CCNPP Specification 2.4.4 and need not be considered in the design of the TC.

Table 9-1
Material Properties – SA-240/SA-479 Type 304
ASTM A-240, Type 304 (TC)

Nominal Composition: 18Cr-8Ni

Temp (°F)	E (10^3 ksi)	S_m (ksi)	S_y (ksi)	S_u (ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})	ρ (lb/in^3)	k (Btu/hr-ft-°F)	α (ft^2/hr)
-20		20.0	30.0	75.0					
70	28.3				8.46	8.46		8.6	0.151
100		20.0	30.0	75.0	8.63	8.55		8.7	0.152
150					8.87	8.67			
200	27.6	20.0	25.0	71.0	9.08	8.79		9.3	0.156
250					9.27	8.90			
300	27.0	20.0	22.5	66.0	9.46	9.00		9.8	0.160
350					9.64	9.10			
400	26.5	18.7	20.7	64.4	9.80	9.19		10.4	0.165
450					9.95	9.28			
500	25.8	17.5	19.4	63.5	10.10	9.37	0.290	10.9	0.170
550					10.25	9.45			
600	25.3	16.4	18.2	63.5	10.38	9.53		11.3	0.174
650		16.2	17.9	63.5	10.50	9.61			
700	24.8	16.0	17.7	63.5	10.60	9.69		11.8	0.179
750		15.6	17.3	63.1	10.70	9.76			
800	24.1	15.2	16.8	62.7	10.79	9.82		12.2	0.184
850			16.5	61.9					
900	23.5		16.2	61.0				12.7	0.189
950			15.9	59.4					
1000			15.6	57.7				13.2	0.194
SA-240, 304 or A-240, 304	Table TM-1 pg 664 Group G	Table 2A pg 354	Table Y-1 pg 573.1	Table U pg 494	Table TE-1 pg 640		Perry Table 23-5	Calculated based on Table TCD pg 656	
SA-479, 304	Table TM-1 pg 664 Group G	Table 2A pg 358	Table Y-1 pg 574	Table U pg 496					

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Table 9-2
Material Properties – SA 516, Gr. 70 (TC)

Carbon Steel with C ≤ 0.30% (C-Mn-Si)

Temp (°F)	E (10^3 ksi)	S_m (ksi)	S_y (ksi)	S_u (ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})	ρ (lb/in^3)	k (Btu/hr-ft-°F)	α (ft^2/hr)
-20		23.3	38.0	70.0					
70	29.5				5.42	5.42		23.6	0.454
100		23.3	38.0	70.0	5.65	5.53		23.9	0.443
150					6.03	5.71			
200	28.8	23.1	34.6	70.0	6.39	5.89		24.4	0.422
250					6.73	6.09			
300	28.3	22.5	33.7	70.0	7.04	6.26		24.4	0.406
350					7.33	6.43			
400	27.7	21.7	32.6	70.0	7.60	6.61		24.2	0.386
450					7.85	6.77			
500	27.3	20.5	30.7	70.0	8.07	6.91	0.284	23.7	0.364
550					8.28	7.06			
600	26.7	18.7	28.1	70.0	8.46	7.17		23.1	0.346
650		18.4	27.6	70.0	8.62	7.30			
700	25.5	18.3	27.4	70.0	8.75	7.41		22.4	0.320
750			26.5	69.3	8.87	7.50			
800	24.2		25.3	64.3	8.96	7.59		21.7	0.298
850			24.4	58.6					
900	22.4		24.1	52.0				20.9	0.274
950			23.2	46.2					
1000			21.1	40.3				20.0	0.248
	Table TM-1 pg 664	Table 2A pg 298	Table Y-1 pg 514	Table U pg 480	Table TE-1 pg 638 group C		AISC	Calculated based on Table TCD pg 650	

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Table 9-3
Material Properties – SA 564, Gr. 630 (TC)

Nominal Composition: 17Cr-4Ni-4Cu

Temp (°F)	E (10^3 ksi)	S_m (ksi)	S_y (ksi)	S_u (ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})	ρ (lb/in^3)	k (Btu/hr-ft-°F)	α (ft^2/hr)
-20		45.0	105.0	135.0					
70	28.3				5.89	5.89		9.9	0.188
100		45.0	105.0	135.0	5.89	5.89		10.1	0.189
150					5.89	5.89			
200	27.6	45.0	97.1	135.0	5.90	5.90		10.6	0.189
250					5.90	5.90			
300	27.0	45.0	93.0	135.0	5.90	5.90		11.2	0.190
350					5.91	5.91			
400	26.5	43.8	89.8	131.4	5.91	5.91		11.7	0.191
450					5.91	5.91			
500	25.8	42.8	87.0	128.4	5.91	5.91	0.284	12.2	0.190
550					5.93	5.93			
600	25.3	42.1	84.7	126.7	5.96	5.93		12.7	0.190
650		41.9	83.6		5.99	5.93			
700	24.8				6.03	5.94		13.2	0.186
750					6.08	5.95			
800	24.1				6.14	5.96		13.5	0.180
850									
900	23.5							13.7	0.172
950									
1000								13.8	0.160
	Table TM-1 pg 664 Group G	Table 2A pg 325.1	Table Y-1 pg 546	Table U pg 488	Table TE-1 pg 640		Perry Table 23-5	Calculated based on Table TCD pg 657	

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Table 9-4
Material Properties – SA-182 Type F304N (TC)

Nominal Composition: 18Cr-8Ni-N

Temp (°F)	E (10^3 ksi)	S_m (ksi)	S_y (ksi)	S_u (ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})	ρ (lb/in^3)	k (Btu/hr-ft-°F)	α (ft^2/hr)
-20		23.3	35.0	80.0					
70	28.3				8.46	8.46		8.6	0.151
100		23.3	35.0	80.0	8.63	8.55		8.7	0.152
150					8.87	8.67			
200	27.6	23.3	28.7	80.0	9.08	8.79		9.3	0.156
250					9.27	8.90			
300	27.0	22.5	25.0	75.9	9.46	9.00		9.8	0.160
350					9.64	9.10			
400	26.5	20.3	22.5	73.2	9.80	9.19		10.4	0.165
450					9.95	9.28			
500	25.8	18.8	20.9	71.2	10.10	9.37	0.290	10.9	0.170
550					10.15	9.45			
600	25.3	17.8	19.8	69.7	10.38	9.53		11.3	0.174
650		17.6	19.5	69.1	10.50	9.61			
700	24.8	17.2	19.1	68.6	10.60	9.69		11.8	0.179
750		16.9	18.8	68.0	10.70	9.76			
800	24.1	16.7	18.5	67.2	10.79	9.82		12.2	0.184
850			18.1	66.4					
900	23.5		17.7	65.6				12.7	0.189
950			17.3	64.5					
1000			16.8	62.9				13.2	0.194
	Table TM-1 pg 664 group G	Table 2A pg 358	Table Y-1 pg 578	Table U pg 496	Table TE-1 pg 640		Perry Table 23-5	Calculated based on Table TCD pg 656	

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Table 9-5
Material Properties – SA-193 Gr. B7 (TC)

Temp (°F)	Maximum Allowable Stress Value for Class 2 Component, S (ksi)	Yield Strength, S_y (ksi)
-20	25.0	105.0
100	25.0	105.0
150	25.0	
200	25.0	98.0
300	25.0	94.1
400	25.0	91.5
500	25.0	88.5
550	25.0	
600	25.0	85.3
650	25.0	83.0
700	25.0	80.6
750	23.6	77.5
800	21.0	74.0
850	17.0	
900	12.5	
950	8.5	
	Table 3 pg 424	Table Y-1 pg 530

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Table 9-6
Mechanical Properties for ASTM B29 Lead (DSC and TC)
(Static Properties)

Temp. (°F)	Static Stress Properties (ksi)			E (10^6 psi)	Coef. Of Thermal Exp (10^{-6} in/in/°F)
	Yield (S_Y)		Ultimate (S_U)		
	Tension	Compression	Tension		
-99	-	-	-	2.50	15.28
70	-	-	-	2.34	16.07
100	0.584	0.490	1.570	2.30	16.21
175	0.509	0.428	1.162	2.20	16.58
250	0.498	0.391	0.844	2.09	16.95
325	0.311	0.320	0.642	1.96	17.54
440	-	-	-	1.74	18.50
620	-	-	-	1.36	20.39

Note: The material properties of the lead are based on "Safety Analysis Report for the NUHOMS® - MP187 Multi-Purpose Cask", Docket 71-9255, TN Document Number NUH-05-151, Revision 17, July 2003 (Table 2.3.4-2).

(Dynamic Stress-Strain Properties)

Strain (in/in)	Stress (ksi)				
	100°F	230°F	300°F	350°F	500°F
0.000485	1.14	1.06	1.00	0.97	0.86
0.03	2.2	2.0	1.7	1.5	1.1
0.1	3.3	2.8	2.38	2.1	1.26
0.3	4.9	3.2	2.72	2.4	1.44
0.5	5.6	3.6	3.06	2.7	1.62

Note: The static and dynamic stress properties of the lead are taken from Tietz [2.4.29]. The Young's modulus and coefficient of thermal expansion values are taken from NUREG/CR-0481[2.3.24], Pages 56 and 66.

Table 9-7
Thermal Properties for Lead (DSC and TC)

Thermal Properties			
Temp	Thermal Conductivity	Specific Heat	Density
(K)	(W/m-K)	(kJ/kg-K)	(kg/m^3)
100	39.7	0.118	11,520
150	37.9	0.122	11,470
200	36.7	0.125	11,430
250	36.0	0.127	11,380
300	35.3	0.129	11,330
400	34.0	0.132	11,230
500	32.8	0.137	11,130
600	31.4	0.142	11,010
	Ch. 3, Table68	Ch. 3, Table 67	Ch. 3, Table 64

Reference: Rohsenow, W.M., "Handbook of Heat Transfer", 2nd Edition, McGraw-Hill Handbooks.

Table 9-8
Mechanical and Thermal Properties for NS-3 (TC)

Mechanical Properties		
Poisson Ratio	Compressive Strength (ksi)	Modulus of Elasticity (1.0E3 ksi)
0.2	3.9	0.16
Thermal Properties		
Thermal Conductivity (Btu-in/hr-ft^2-°F)	Specific Heat (Btu/lbm-°F)	Specific Gravity (---)
5.86	0.145	1.76

Reference: Calculations 1095-35, Rev. 2 and Calculation 1095-5, Rev. 0.

Table 9-9
Material Properties – Air (DSC and TC)

Temperature	Thermal conductivity	Temperature	Thermal conductivity
(K)	(W/m-K)	(°F)	(Btu/hr-in-°F)
200	0.01822	-100	0.0009
250	0.02228	-10	0.0011
300	0.02607	80	0.0013
400	0.03304	260	0.0016
500	0.03948	440	0.0019
600	0.04557	620	0.0022
800	0.05698	980	0.0027
1000	0.06721	1340	0.0032

The above data are calculated base on the following polynomial function from: Rohsenow, W.M., "Handbook of Heat Transfer", 3rd Edition, McGraw-Hill Handbooks.

$k = \sum C_i\ T_i$ for conductivity in(W/m-K) and T in (K)

For 250 < T < 1050 K	
C0	-2.2765010E-03
C1	1.2598485E-04
C2	-1.4815235E-07
C3	1.7355064E-10
C4	-1.0666570E-13
C5	2.4766304E-17

Specific heat, viscosity, density and Prandtl number of air are used to calculate heat transfer coefficients based on the following data from: Rohsenow, W.M., "Handbook of Heat Transfer", 3rd Edition, McGraw-Hill Handbooks.

$c_p = \sum A_i\ T_i$ for specific heat in (kJ/kg-K) and T in (K)

For 250 < T < 1050 K	
A0	0.103409E+1
A1	-0.2848870E-3
A2	0.7816818E-6
A3	-0.4970786E-9
A4	0.1077024E-12

$\mu = \sum B_i\ T_i$ for viscosity $(N\text{-}s/m^2)\times 10^6$ and T in (K)

For 250 < T < 600 K	
B0	-9.8601E-1
B1	9.080125E-2
B2	-1.17635575E-4
B3	1.2349703E-7
B4	-5.7971299E-11

For 600 < T < 1050 K	
B0	4.8856745
B1	5.43232E-2
B2	-2.4261775E-5
B3	7.9306E-9
B4	-1.10398E-12

$\rho = P/RT$ for density (kg/m^3) with P=101.3 kPa; R = 0.287040 kJ/kg-K; T = air temp in (K);

$Pr = c_p\ \mu / k$ Prandtl number

Table 9-10
Structural Stress Criteria for Transfer Cask

Item	Stress Type	Stress Values			
		Service Levels A & B	Service Level C	Service Level D (Elastic Analysis)	Service Level D (Plastic Analysis)
Transfer Cask Structural Shell	Primary Membrane	S_m	1.2 S_m	Smaller of 2.4 S_m or 0.7 S_u	Larger of 0.7 S_u or $S_y + \frac{(S_u - S_y)}{3}$
	Primary Membrane + Bending	1.5 S_m	1.8 S_m	Smaller of 3.6 S_m or S_u	0.9 S_u
	Primary + Secondary	3.0 S_m	N/A	N/A	N/A
Trunnions(1)	Membrane and Membrane + Bending	Smaller of $S_y/6$ or $S_u/10$	N/A	N/A	N/A
	Shear	Smaller of $S_y/6$ or $S_u/10$	N/A	N/A	N/A
Fillet Welds	Primary	0.5 S_m	0.6 S_m	Smaller of 1.2 S_m or 0.35 S_u	N/A
	Secondary	0.75 S_m	N/A	N/A	N/A

Notes:

(1) These allowables apply to the upper lifting trunnions for cask vertical lifts within the Auxiliary/Fuel Building. The lower support trunnions and the upper lifting trunnions for all remaining loads are governed by the same ASME Code criteria applied to the cask structural shell.

Table 9-11
Structural Stress Criteria for Transfer Cask Bolts

Service Levels A, B, and C	
Average Service Stress	< 2 S_m
Maximum Service Stress	< 3 S_m
Service Level D	
Average Tension	Smaller of S_y or 0.7 S_u
Tension + Bending	S_u
Average Shear	Smaller of 0.6 S_y or 0.42 S_u
Interaction	Interaction equation of Appendix F (F-1335.3) of ASME Code [2.1.4]

10.0 HSM-HB STRUCTURAL DESIGN CRITERIA

The HSM-HB design criteria are the same as those utilized for the HSM-H with the 24PTH/32PTH DSCs and documented in CoC 1004 UFSAR, Appendix P of [2.4.4] and in CoC 1030 SAR [2.4.13].

11.0 THERMAL REQUIREMENTS

Thermal properties of materials including material temperature limits should be traced to authoritative references. For materials not listed in appropriate references, thermal properties shall be obtained by testing or from other verifiable sources.

Thermal analysis for the 32PHB shall be based on fuel assemblies with decay heat up to 29.6 kW per canister. Zoning is used to accommodate per assembly heat loads as high as 1.0 kW as shown in Figure 4-1. The DSC system shall be passively cooled as required in 10 CFR 72.236(f).

Forced air circulation may be required for transfer operation. Time to initiate air circulation following drainage of the TC/DSC annulus shall be greater than or equal to 20 hours for the maximum heat load.

In addition to evaluation of the design basis heat load, the design shall also identify maximum heat loads with uniform heat load zoning configurations, which allow forced cooling initiation times of 48 hours and 72 hours.

Peak clad temperature of the fuel at the beginning of the long term storage shall not exceed 400°C for normal conditions of storage, and for short-term operations, including canister drying and backfilling, according to ISG 11, Revision 3 [2.3.23].

Fuel cladding (Zircaloy) temperature shall be maintained below 570°C (1058°F) [2.3.23] for off-normal and accident conditions.

For DSC unloading operations, cladding integrity should be maintained during reflooding, so as not to interfere with fuel handling and retrieval.

Decay heat shall be calculated with the radiological source terms.

Insolation is 82 Btu/hr-ft^2 for normal conditions and 127 Btu/hr-ft^2 for off-normal and accident conditions based on [2.4.4], Section 3.5.1.

Fuel cladding and basket material temperatures should be calculated assuming steady state conditions during vacuum drying operations. If calculated temperatures are not acceptable, transient analysis should be performed assuming limited time period for vacuum drying operations. The blowdown during vacuum drying operation may be performed using helium or nitrogen.

Based on ISG-11, Rev. 3 [2.3.23], repeated thermal cycling of the cladding during fuel loading operations is limited to ten cycles and the thermal cycling of the cladding with temperature reductions greater than 65°C is not permitted.

Transfer Cask, HSM-HB, DSC, and Fuel Cladding materials shall be maintained within their minimum and maximum temperature criteria for normal, off-normal and accident conditions.

Assume for analysis purposes that all HSM-HB inlet or all outlet vents are blocked.

12.0 SHIELDING REQUIREMENTS

The design basis neutron and gamma source terms are provided by Constellation Energy, Nuclear Generation Group and shown in Table 4-4 through Table 4-6. Upholding the restrictions on the number of the reconstituted fuel rods and the requirements for additional cooling time specified in [2.4.30] and [2.4.31], the source terms presented in Table 4-4 through Table 4-6 are applicable for reconstituted fuel assemblies.

The 32PHB DSC shall be designed to limit radiation exposure to both operators and the general public in accordance with ALARA.

For storage the radiation shielding must meet the requirements of 10CFR72.104 and 10CFR72.106.

Based on [2.4.4], Section 3.6, the dose rates shall be limited to the following values:

- Contact dose rate on the exterior surface of the transfer cask ≤ 250 mrem/hr
- Contact dose rate on the exterior surface of the HSM-HB shield door ≤ 100 mrem/hr
- Contact dose rate on the exterior surface of the HSM-HB sides and roof, excluding the vents ≤ 20 mrem/hr

After a design basis accident an individual at the boundary or outside the controlled area shall not receive a dose rate greater than 5 rem to the whole body or to any organ.

Doses calculated for workers and the public shall comply with the criteria in 10 CFR 20 and 72.

Gammas with energies from approximately 0.8 to 2.5 Mev will be considered as significant contributors to the dose rate.

The contribution from the irradiated fuel assembly hardware to the source term and the dose rate shall also be considered.

The flux-to-dose rate conversion factor shall be based on ANSI/ANS 6.1.1-1977.

Degradation of shielding material at higher temperature, if applicable, shall be accounted for in the shielding evaluation.

13.0 CRITICALITY REQUIREMENTS

The criticality analysis shall determine the minimum poison loading requirements as a function of fuel enrichment. The loading requirements are the thickness and minimum absorber loading (B10) utilized in the criticality analysis and the type of poison, if the analysis establishes a statistically significant variation in the system reactivity due to poison type. The credit for the amount of the absorber material in the criticality analysis shall be detailed in the material specification based on the poison material like, borated aluminum alloy or metal matrix composites (MMCs) following requirements of NUREG CR-5661 [2.3.21]. Poison plates may be composed entirely of borated material or may be thinner borated sheet paired with aluminum sheet to achieve the required thickness.

13.1 General Criticality Criteria

No credit for burnable poison materials within the fuel assemblies as a neutron absorber shall be taken.

For a single DSC or an array of DSCs, the effective criticality factor, k_{eff}, shall not exceed 0.95 with a 95% probability at a 95% confidence level including uncertainties under all credible normal, off-normal, and accident conditions. Model bias and benchmarking bias shall be accounted for in the criticality analysis.

Assume no more than 90% of the poison material is effective for MMC and borated aluminum. To allow 90% credit poison material coupons shall be tested via neutron transmission plus radiography.

Criticality analysis shall consider reconstituted fuel that replaces same amount of water as the original fuel pins.

The canister shall be designed and fabricated such that the spent fuel is maintained in a subcritical condition under all credible normal, off-normal, and accident conditions (10 CFR 72.124(a) and 72.23(c)).

The criticality analysis shall demonstrate that the fuel assembly used as the design basis is the most reactive. For the fuel assemblies with axial variation in enrichments, criticality analysis shall demonstrate that the maximum enrichment selected for the fuel assemblies is bounding.

The criticality analysis needs to consider bounding enrichments from the values given in Table 4-2.

The criticality analysis must demonstrate that the DSC remains subcritical for all credible conditions of moderation.

Criticality control shall be demonstrated with a combination of fixed geometry, neutron poison in the basket, and soluble Boron in the pool, as appropriate. Credit for soluble boron shall be limited to 2600 ppm.

To ensure the compliance with the criticality acceptance criteria of $k_{eff} < 0.95$ as delineated in ANSI/ANS 57.2 - 1983, full and optimum moderator density conditions over 0.1 to 1.0 g/cc range shall be considered during wet loading and unloading of the fuel assemblies.

The fuel assembly misloading will not be considered for criticality evaluation.

14.0 CONFINEMENT/CONTAINMENT CRITERIA

The canister must maintain confinement of radioactive material within the limits of 10 CFR 72.236(l) and 10 CFR 20 under normal, off-normal, and credible accident conditions.

Canister shall be designed and tested to meet the leak-tight criteria defined in ISG-18 [2.3.23] and ANSI N14.5, Ref. [2.1.8].

15.0 ACCEPTANCE TESTING

Testing for the 32PHB DSC shall include those required by the ASME Code for the qualification of materials, welded joints, and canister leakage per ANSI N14.5-1997. Additionally, specific operational type fit-up testing is required. Specific tests required shall be specified in the appropriate drawings or included in the canister fabrication specification.

The following minimum testing shall be performed:

- ASME Code required testing (materials and welding),
- Helium leak testing of the final pressure boundary to a "leak tight" condition as defined by ANSI N14.5 –1997,
- Dummy fuel assembly insertion and withdrawal for each basket fuel compartment, and,
- Testing of the poison matrix material. These tests shall provide the justification for assuming that 90% of the poison material is effective for metal matrix composite and borated aluminum.

DSC shell assembly closure welds shall be in accordance with the guidance of NRC's Interim Staff Guidance ISG-15 [2.3.23]. Other 32PHB DSC basket welds shall identify efficiency factors and inspection criteria in the calculation.

16.0 MATERIAL REQUIREMENTS

16.1 Specifications

Materials meeting the requirements of ASME B&PV Code, Section III, Article NB-2000, and the specification requirements of Section II, shall be used in the design to the maximum extent practical.

Detailed procurement specifications shall be required for other materials to assure that mechanical and other property values used in the design calculations will be met.

16.2 Properties

The material properties, stress intensity values and allowable stresses shall be obtained from the ASME B&PV Code, Section II, Part D.

For other materials, the source of material property data shall be identified and documented.

Materials shall be selected based on their corrosion resistance, susceptibility to stress corrosion cracking, embrittlement properties, and the environment in which they operate during normal and accident conditions. The lowest service temperature for metallic component in the DSC is -8°F.

16.3 Impact Properties Test

The 32PHB DSC components shall be evaluated for their impact properties and shall meet the requirements of the applicable material specifications (ASME B&PV Code, Section II) and ASME B&PV Code Section III, Subsection NB-2000 and Subsection NG-2000.

16.4 Materials Suitability (Chemical, Galvanic and Other Reactions)

Materials suitability shall be reviewed in accordance with 10 CFR 72, NRC Bulletin 96-04 and 10CFR71.44 (d). Materials and construction shall be selected to assure that there will be no significant chemical, galvanic, or other reaction among packaging components and contents.

Materials shall be chosen that will preclude a galvanic effect that could lead to unacceptable fuel cladding corrosion or generate flammable gases in unacceptable quantities. Combustible gases should not exceed 2.4% of free gas volume in any confined region for both normal and hypothetical accident conditions [2.4.21].

Material suitability evaluation should include:

- the possible reaction from water inleakage,
- the behavior of materials under irradiation, and

- the behavior materials during all operations, e.g. operating temperatures and loading pool environment.

16.5 Protective Coatings

The materials used for protective coatings (if required) shall be compatible with the DSC materials, operating temperatures, loading pool environment and other interfacing materials or components.

16.6 Emissivities

Emissivity values for various surfaces important for heat transfer shall be specified in the calculations. The stainless steel emissivity in calculation of the effective fuel conductivity shall remain between 0.3 and 0.35.

16.7 Effects of Radiation

Construction materials shall be compatible with the expected radiation levels.

16.8 Prohibited / Hazardous Materials

The design shall not include sulfur, mercury, asbestos, low melting point metals, their alloys or components.

Materials in contact with pool water shall not release materials that contain chlorine or other halogens, sulfur, nitrates, mercury, lead, zinc, copper, tin, gallium, arsenic, antimony, bismuth, silver, cadmium or indium.

17.0 QUALITY ASSURANCE REQUIREMENTS

The Important to Safety components of the NUHOMS® 32PHB DSC shall be designed, in accordance with the most recent revision of Transnuclear's Quality Assurance Program.

ATTACHMENT (2)

AREVA TN AFFIDAVIT

AFFIDAVIT PURSUANT
TO 10 CFR 2.390

AREVA Inc.)
State of Maryland) SS.
County of Howard)

I, Paul Triska, depose and say that I am a Vice President of AREVA Inc., duly authorized to execute this affidavit, and have reviewed or caused to have reviewed the information that is identified as proprietary and referenced in the following paragraph. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.390 of the Commission's regulations for withholding this information.

The information for which proprietary treatment is sought is contained in a procurement specification to be used in responses to Requests for Additional Information, as listed below:

- NUH32P-0105 Revision 1 "Procurement Specification for the NUHOMS® 32P and 32PHB Dry Shielded Canisters"

I have personal knowledge of the criteria and procedures utilized by AREVA Inc., in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1) The information sought to be withheld from public disclosure involves fabrication methods and instructions for dry spent fuel storage systems, which are owned and have been held in confidence by AREVA Inc.

2) The information is of a type customarily held in confidence by AREVA Inc., and not customarily disclosed to the public. AREVA Inc. has a rational basis for determining the types of information customarily held in confidence by it.

3) Public disclosure of the information is likely to cause substantial harm to the competitive position of AREVA Inc., because the information is related to the design and fabrication of the NUHOMS® 32P and 32PHB Dry Shielded Canister. The availability of such information to competitors would enable them to modify their product to better compete with AREVA Inc., take marketing or other actions to improve their product's position or impair the position of AREVA Inc.'s product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

Further the deponent sayeth not.

Paul Triska
Vice President, Technical Services

Subscribed and sworn to me before this 9th day of October, 2014.

Notary Public

My Commission Expires 11/17/2014

Patricia Hoch
Notary Public
Howard County, MD
My Commission Expires Nov. 17, 2014