72-1004

TRANSNUCLEAR WEST

July 15, 2000
RMG-00-018
NUH61B-TNW0007-01

Mr. Steven Baggett
Spent Fuel Project Office, NMSS
U. S. Nuclear Regulatory Commission
11555 Rockville Pike M/S 0-6-F-18
Rockville, MD 20852

Subject: Application for Amendment No.3 of NUHOMS® Certificate of Compliance No. 1004 for Dry Spent Fuel Storage Casks, Revision 0

References:
1. Federal Register Notice 3150-AG34 published June 22, 2000.
2. Certificate of Compliance (CofC) No. 1004 Rev. No. 2 Effective September 5, 2000.
3. Standard Review Plan for Dry Cask Storage Systems, NUREG-1536, January 1997.

Dear Mr. Baggett:

Transnuclear West Inc. (TN West) herewith submits Revision 0 of its Application for Amendment No. 3 of NUHOMS® Certificate of Compliance No. 1004. This application proposes to add another Dry Shielded Canister (DSC), designated the NUHOMS®-61BT DSC, to the authorized contents of the Standardized NUHOMS® System.

Transnuclear, Inc. is currently in discussions with three utilities, including two operating plants, for dry storage systems using the 61BT DSC. These utilities have immediate needs for dry storage. Fabrication of new canisters will begin in early 2001 in order to support loading in early 2002.

The NUHOMS®-61BT DSC is a transportable canister designed to accommodate 61 BWR fuel assemblies. It is designed for use with the existing NUHOMS® Horizontal Storage Module (HSMs) and the OS-197 transfer cask. No change to the HSM or transfer cask designs is required to accommodate the new canister.

Transnuclear West Inc.
39300 Civic Center Drive, Suite 280, Fremont, CA 94538
Phone: 510-795-9800 ◆ Fax: 510-744-6002

NMSS01 Prop

A new 61 BWR assembly basket has been incorporated into the NUHOMS®-61BT DSC. The new basket design draws heavily on the TN-68 basket design, which has been recently licensed by the NRC. Other design features of the NUHOMS® canister design have been maintained in order to minimize new areas of review and allow this amendment to be reviewed in an expeditious manner.

The operations of the NUHOMS® systems are only minimally affected by the new canister. These effects are fully addressed in Attachment C.

This submittal is organized in the following format to facilitate your staff's review:

Attachment A: Description, Justification and Evaluation of Amendment Changes,
Attachment B: Suggested Changes to Certificate of Compliance (Relative to Reference 1),
Attachment C: Proposed Appendix K of the CSAR Rev. 5A, and
Attachment D: Supporting Calculation Packages (Proprietary Information).

Appendix K includes a complete evaluation of the NUHOMS®-61BT DSC and is prepared in a format consistent with the Standard Review Plan for Dry Cask Storage. Where analyses are bounded by the existing SAR, those sections of the SAR are referenced.

CSAR Rev. 5A and the proposed revised pages to incorporate the NUHOMS®-61BT will be submitted under separate cover within 3 weeks. CSAR Rev. 5A incorporates changes to the SAR as a result of Amendment 1 of Certificate of Compliance 1004 and all Condition 9 changes made since issuance of Rev. 4A through March 31, 2000.

This submittal includes proprietary calculation packages (Attachment D) and drawings (contained in Section K.1.5 of Attachment C) that may not be used for any purpose other than to support your staff's review of the application. In accordance with 10 CFR 2.790, we are providing an affidavit (Enclosure 1) specifically requesting that you withhold this proprietary information from public disclosure.

We look forward to working with you on this amendment. TN West is prepared to meet with you shortly after you have received this amendment to discuss the contents of the submittal and resolve any questions you might have. Should you or your staff require additional information to support review of this application, please do not hesitate to contact Mr. U. B. Chopra (510-744-6053) or me (510-744-6020).

Sincerely,

Robert M. Grenier

Robert M. Grenier
President and Chief Operating Officer

Docket 72-1004

Attachment: 1. Affidavit for withholding proprietary information.

2. Ten (10) copies of Application for Amendment No. 3 to COC 1004

AFFIDAVIT PURSUANT TO 10 CFR 2.790

Transnuclear West Inc.)
State of California) SS.
County of Alameda)

I, Robert M. Grenier, depose and say that I am President and Chief Operating Officer of Transnuclear West Inc., duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.790 of the Commission's regulations for withholding this information.

The information for which proprietary treatment is sought is contained in the documents included in Attachment C and Attachment D of this submittal and as listed below:

Calculation NUH61B.0600, Revision 0
TN West Drawing NUH-61B-1060, Revision 0
TN West Drawing NUH-61B-1061, Revision 0
TN West Drawing NUH-61B-1062, Revision 0
TN West Drawing NUH-61B-1063, Revision 0
TN West Drawing NUH-61B-1064, Revision 0

These sections of the document have been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by Transnuclear West 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 2.790 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 is design drawings and calculations of NUHOMS® Cask, which is owned and has been held in confidence by Transnuclear West Inc.

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

3) The information is being transmitted to the Commission in confidence under the provisions of 10 CFR 2.790 with the understanding that it is to be received in confidence by the Commission.

4) The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been made pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence.

5) Public disclosure of the information is likely to cause substantial harm to the competitive position of Transnuclear West Inc. because:

a) A similar product is manufactured and sold by competitors of Transnuclear West Inc.

b) Development of this information by Transnuclear West Inc. required thousands of man-hours and hundreds of thousands of dollars. To the best of my knowledge and belief, a competitor would have to undergo similar expense in generating equivalent information.

c) In order to acquire such information, a competitor would also require considerable time and inconvenience related to the development of a design and analysis of a dry spent fuel storage system.

d) The information required significant effort and expense to obtain the licensing approvals necessary for application of the information. Avoidance of this expense would decrease a competitor's cost in applying the information and marketing the product to which the information is applicable.

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f) In pricing Transnuclear West's products and services, significant research, development, engineering, analytical, licensing, quality assurance and other costs and expenses must be included. The ability of Transnuclear West's competitors to utilize such information without similar expenditure of resources may enable them to sell at prices reflecting significantly lower costs.

Further the deponent sayeth not.

Robert M. Grenier
President and Chief Operating Officer
Transnuclear West Inc.

Subscribed and sworn to me before this 14th day of July, 2000, by Robert M. Grenier.

Notary Public

SHANNON L. CHRISTENSEN
COMM. # 1264196
NOTARY PUBLIC-CALIFORNIA
ALAMEDA COUNTY
COMM. EXP. MAY 18, 2004

JP

TRANSNUCLEAR WEST

AMENDMENT NO. 3 TO NUHOMS® COC 1004

ADDITION OF 61BT DSC TO STANDARDIZED NUHOMS® SYSTEM

TRANSNUCLEAR WEST

July 15, 2000
RMG-00-018
NUH61B-TNW0007-01

Mr. Steven Baggett
Spent Fuel Project Office, NMSS
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11555 Rockville Pike M/S 0-6-F-18
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The NUHOMS®-61BT DSC is a transportable canister designed to accommodate 61 BWR fuel assemblies. It is designed for use with the existing NUHOMS® Horizontal Storage Module (HSMs) and the OS-197 transfer cask. No change to the HSM or transfer cask designs is required to accommodate the new canister.

Transnuclear West Inc.
39300 Civic Center Drive, Suite 280, Fremont, CA 94538
Phone: 510-795-9800 ♦ Fax: 510-744-6002

A new 61 BWR assembly basket has been incorporated into the NUHOMS®-61BT DSC. The new basket design draws heavily on the TN-68 basket design, which has been recently licensed by the NRC. Other design features of the NUHOMS® canister design have been maintained in order to minimize new areas of review and allow this amendment to be reviewed in an expeditious manner.

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Attachment D: Supporting Calculation Packages (Proprietary Information).

Appendix K includes a complete evaluation of the NUHOMS®-61BT DSC and is prepared in a format consistent with the Standard Review Plan for Dry Cask Storage. Where analyses are bounded by the existing SAR, those sections of the SAR are referenced.

CSAR Rev. 5A and the proposed revised pages to incorporate the NUHOMS®-61BT will be submitted under separate cover within 3 weeks. CSAR Rev. 5A incorporates changes to the SAR as a result of Amendment 1 of Certificate of Compliance 1004 and all Condition 9 changes made since issuance of Rev. 4A through March 31, 2000.

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Notary Public

SHANNON L. CHRISTENSEN
COMM. # 1264196
NOTARY PUBLIC-CALIFORNIA
ALAMEDA COUNTY
COMM. EXP. MAY 18, 2004

<u>ATTACHMENT A</u>

Description, Justification, and Evaluation of COC Amendment Changes

ATTACHMENT A

DESCRIPTION, JUSTIFICATION AND EVALUATION OF AMENDMENT CHANGES

1.0 INTRODUCTION

The purpose of this amendment application is to add a third Dry Shielded Canister (DSC), the NUHOMS®-61BT DSC, to the authorized contents of the Standardized NUHOMS® System.

This section of the application provides (1) a brief description of the changes, (2) justification for the change, and (3) a safety evaluation for this change.

2.0 BRIEF DESCRIPTION OF THE CHANGE

2.1 Significant Changes to NUHOMS® COC 72-1004, Revision 2

The NRC staff has issued a Revision 2 (Direct final rule) in Federal Register Number 38715 in Volume 65, Number 121, dated June 22, 2000 to NUHOMS® COC 72-1004. The changes listed below are relative to COC Revision 2 which is effective September 5, 2000.

- Revise "Limit/Specification" and "Action" sections of Specification 1.2.1, "Fuel Specification", to add reference to Tables 1-1c and 1-1d. Table 1-1c and 1-1d show the applicable parameters for each type of BWR fuel allowed to be stored in the NUHOMS®-61BT DSC.
- Revise the "Bases" section of Specification 1.2.1, "Fuel Specification", to provide the supporting basis for storage of BWR fuel in the NUHOMS®-61BT DSC.
- Add Table 1-1c to clearly identify the acceptable parameters for each type of Intact BWR fuel allowed to be stored in the NUHOMS®-61BT DSC.
- Add Table 1-1d to clearly identify the acceptable parameters for each type of Intact/Damaged BWR fuel allowed to be stored in the NUHOMS®-61BT DSC.
- Revise the title and "Applicability" section of Specification 1.2.3, "Helium Backfill Pressure", to restrict it's applicability to the 24P (standard and long cavity) DSCs, and 52B DSCs.
- Add Specification 1.2.3a, "61BT DSC Helium Backfill Pressure. This specification is identical to 1.2.3 except the allowed tolerance on the helium backfill pressure is reduced from ±2.5 psig to ±1.0 psig.
- Revise the title and "Applicability" section of Specification 1.2.4, "Helium Leak Rate of Inner Seal Weld", to restrict it's applicability to the 24P, 24P long cavity, and 52B DSCs.

- Add Specification 1.2.4a, "61BT DSC Helium Leak Rate of Inner Seal Weld". This specification requires that the NUHOMS®-61BT top cover plate seal weld be tested to meet the "leak tight" requirements as specified in ANSI N14.5-1997.

- Revise the "Bases" section of Specification 1.2.7, "HSM Dose Rates", to include a reference to Appendix K where the shielding analysis for 61BT system is located.

- Revise the "Bases" section of Specification 1.2.11, "Transfer Cask Dose Rates to include a reference to Appendix K where the shielding analysis for 61BT system is located.

- Revise the "Applicability" section of Specification 1.2.15, "Boron Concentration in the DSC Cavity Water (24-P Design Only)", to clearly state that this specification also does not apply to the NUHOMS®-61BT system.

- Add Specification 1.2.17, "Vacuum Drying Duration Limit". This specification places a 96 hour duration limit on Vacuum Drying the NUHOMS®-61BT DSC.

- Update Table 1.3.1 for the additional sections added to the specification.

2.2 Changes to NUHOMS® CSAR, Revision 5A

Attachment C of this submittal includes a new CSAR Appendix K, "Evaluation Of Addition Of NUHOMS® 61BT DSC To NUHOMS ® System". Appendix K has been prepared in a format consistent with the Standard Review Plan for Dry Cask Storage (NUREG 1536). It provides a complete evaluation of the new basket and the revised design features of the DSC. It also documents the changes where applicable to the existing safety analyses provided in the CSAR.

CSAR Revision 5A and the proposed revised pages to incorporate the NUHOMS® 61BT will be submitted within three weeks of this submittal. CSAR Revision 5A incorporates changes to the SAR as a result of Amendment No. 1 to NUHOMS® COC 1004 and all Condition 9 changes implemented since issuance of Revision 4A through March 31, 2000.

3.0 JUSTIFICATION OF CHANGE

The NUHOMS®-61BT System design has been developed based on research and development efforts driven by the commercial nuclear power industry identified needs. TNW believes that the NUHOMS®-61BT System is required to optimally support the commercial nuclear industry in their effort to maintain full core off-load capability and support near term decommissioning activities. TNW is currently having discussions with several nuclear power utilities regarding the near term use of the NUHOMS®-61BT at their facilities.

4.0 EVALUATION OF CHANGE

TN West has evaluated the NUHOMS®-61BT system for structural, thermal, shielding and criticality adequacy and has concluded that the addition of the new DSC to the standardized NUHOMS® System has no significant effect on safety. This evaluation is documented in

Appendix K of the CSAR (Attachment C). Supporting calculations are included in Attachment D.

ATTACHMENT B

Suggested Changes to Certificate of Compliance No. 1004 Revision No. 2 (Effective September 5, 2000)

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1.1.2 Operating Procedures

Written operating procedures shall be prepared for cask handling, loading, movement, surveillance, and maintenance. The operating procedures suggested generically in the SAR were considered appropriate as discussed in Section 11.0 of the SER and should provide the basis for the user's written operating procedure. The following additional procedure requested by NRC staff in Section 11.1 should be part of the user operating procedures:

> If fuel needs to be removed from the DSC, either at the end of service life or for inspection after an accident, precautions must be taken against the potential for the presence of damaged or oxidized fuel and to prevent radiological exposure to personnel during this operation. This can be achieved with this design by the use of the purge and fill valves which permit a determination of the atmosphere within the DSC before the removal of the inner top cover plate and shield plugs, prior to filling the DSC cavity with water (*borated water for the 24P,* see SAR paragraph 5.1.1.9). If the atmosphere within the DSC is helium, then operations should proceed normally with fuel removal either via the transfer cask or in the pool. However, if air is present within the DSC, then appropriate filters should be in place to preclude the uncontrolled release of any potential airborne radioactive particulate from the DSC via the purge-fill valves. This will protect both personnel and the operations area from potential contamination. For the accident case, personnel protection in the form of respirators or supplied air should be considered in accordance with the licensee's Radiation Protection Program.

1.1.7 Special Requirements for First System in Place

The heat transfer characteristics of the cask system will be recorded by temperature measurements of the first DSC placed in service. The first DSC shall be loaded with assemblies, constituting a source of approximately 24 kW. The DSC shall be loaded into the HSM, and the thermal performance will be assessed by measuring the air inlet and outlet temperatures for normal airflow. Details for obtaining the measurements are provided in Section 1.2.8, under "Surveillance."

A letter report summarizing the results of the measurements shall be submitted to the NRC for evaluation and assessment of the heat removal characteristics of the cask in place within 30 days of placing the DSC in service, in accordance with 10 CFR 72.4.

Should the first user of the system not have fuel capable of producing a 24 kW heat load, or be limited to a lesser heat load, as in the case of BWR fuel, the user may use a lesser load for the process, provided that a calculation of the temperature difference between the inlet and outlet temperatures is performed, using the same methodology and inputs documented in the SAR, with lesser load as the only exception. The calculation and the measured temperature data shall be reported to the NRC in accordance with 10 CFR 72.4. The calculation and comparison need not be reported to the NRC for DSCs that are subsequently loaded with lesser loads than the initial case. However, for the first or any other user, the process needs to be performed and reported for any higher heat sources, up to 24 kW for PWR fuel *stored in the 24P,* 19 kW for BWR fuel *stored in the 52B and 18.3 kW for BWR fuel stored in the 61BT*, which is the maximum allowed under the Certificate of Compliance. The NRC will also accept the use of artificial thermal loads other than spent fuel, to satisfy the above requirement.

1.2.1 Fuel Specifications

Limit/Specification: The characteristics of the spent fuel which is allowed to be stored in the standardized NUHOMS® system are limited by those included in Tables 1-1a, 1-1b, *1-1c and 1-1d.*

Applicability: The specification is applicable to all fuel to be stored in the standardized NUHOMS® system.

Objective: The specification is prepared to ensure that the peak fuel rod cladding temperatures, maximum surface doses, and nuclear criticality effective neutron multiplication factor are below the design limits. Furthermore, the fuel weight and type ensures that structural conditions in the SAR bound those of the actual fuel being stored.

Action: Each spent fuel assembly to be loaded into a DSC shall have the parameters listed in Tables 1-1a, 1-1b, *1-1c and 1-1d* verified and documented. Fuel not meeting this specification shall not be stored in the standardized NUHOMS® system.

Surveillance: Immediately, before insertion of a spent fuel assembly into a DSC, the identity of each fuel assembly shall be independently verified and documented.

Bases: The specification is based on consideration of the design basis parameters included in the SAR and limitations imposed as a result of the staff review. Such parameters stem from the type of fuel analyzed, structural limitations, criteria for criticality safety, criteria for heat removal, and criteria for radiological protection. The standardized NUHOMS® system is designed for dry, horizontal storage of irradiated light water reactor (LWR) fuel. The principal design parameters of the fuel to be stored can accommodate standard PWR fuel designs manufactured by Babcock and Wilcox (B&W), Combustion Engineering, and Westinghouse, and standard BWR fuel manufactured by General Electric. The *NUHOMS®-24P and 52B* system*s are* limited for use to these standard designs and to equivalent designs by other manufacturers as listed in Chapter 3 of the SAR. The analyses presented in the SAR are based on non-consolidated, zircaloy-clad fuel with no known or suspected gross breaches.

The NUHOMS®-61BT system is limited for use to these standard designs and to equivalent designs by other manufacturers as listed in Appendix K of the SAR. The analyses presented in Appendix K of the SAR are based on non-consolidated, zircaloy-clad fuel. Appendix K also analyzes storage of some fuel with known or suspected gross breaches in the NUHOMS®-61BT DSC.

The physical parameters that define the mechanical and structural design of the HSM and DSC are the fuel assembly dimensions and weight. The calculated stresses given in the SAR are based on the physical parameters given in Tables 1-1a, 1-1b, *1-1c and 1-1d* and represent the upper bound.

The design basis fuel assemblies for nuclear criticality safety are Babcock and Wilcox 15x15 fuel assemblies, General Electric 7x7 fuel assemblies *and General Electric 10x10 fuel assemblies* for the standardized NUHOMS®-24P, NUHOMS®-52B *and NUHOMS®-61BT* designs, respectively.

The NUHOMS® 24P Long Cavity DSC is designed for use with standard Burnable Poison Rod Assembly (BPRA) designs for the B&W 15x15 and Westinghouse 17x17 fuel types as listed in Appendix J of the SAR.

The design basis PWR BPRA for shielding source terms and thermal decay heat load is the Westinghouse 17x17 Pyrex Burnable Absorber, while the DSC internal pressure analysis is limited by B&W 15x15 BPRAs. In addition, BPRAs with cladding failures were determined to be acceptable for loading into NUHOMS® 24P Long Cavity DSC as evaluated in Appendix J of the SAR.

The NUHOMS®-24P is designed for unirradiated fuel with an initial fuel enrichment of up to 4.0 wt. % U-235, taking credit for soluble boron in the DSC cavity water during loading operations. Section 1.2.15 defines the requirements for boron concentration in the DSC cavity water for the NUHOMS®-24P design only. In addition, the fuel assemblies qualified for storage in NUHOMS®-24P DSC have an equivalent unirradiated enrichment of less than or equal to 1.45 wt. % U-235. Figure 1.1 defines the required burnup as a function of initial enrichment. The NUHOMS®-52B is designed for unirradiated fuel with an initial enrichment of less than or equal to 4.0 wt. % U-235.

The NUHOMS®-61BT is designed for unirradiated fuel with an initial enrichment of less than or equal to 4.4 wt. % U-235.

The thermal design criterion of the fuel to be stored is that the total maximum heat generation rate per assembly and BPRA be such that the fuel cladding temperature is maintained within established limits during normal and off-normal conditions. Fuel cladding temperature limits were established based on methodology in PNL-6189 and PNL-4835.

The radiological design criterion is that fuel stored in the NUHOMS® system must not increase the average calculated HSM or transfer cask surface dose rates beyond those calculated for a canister full of design basis fuel assemblies with or without BPRAs. The design value average HSM and cask surface dose rates were calculated to be 48.6 mrem/hr and 591.8 mrem/hr respectively based on storing twenty four (24) Babcock and Wilcox 15x15 PWR assemblies (without BPRAs) with 4.0 wt. % U-235 initial enrichment, irradiated to 40,000 MWd/MTU, and having a post irradiation time of five years. To account for BPRAs, the fuel assembly cooling required cooling times are increased to maintain the above dose rate limits.

Table 1-1c
BWR Fuel Specifications of Intact Fuel to be Stored in the Standardized NUHOMS®-61BT DSC

Physical Parameters:	
Fuel Design:	7x7, 8x8, 9x9, or 10x10 BWR fuel assemblies manufactured by General Electric or equivalent reload fuel
Cladding Material:	Zircaloy
Fuel Damage:	Cladding damage in excess of pinhole leaks or hairline cracks is not authorized to be stored as "Intact BWR Fuel".
Channels:	Fuel may be stored with or without fuel channels
Maximum Assembly Length	176.2 in
Maximum Assembly Width	5.44 in
Maximum Assembly Weight	705 lbs
Radiological Parameters:	
Group 1:	
Maximum Burnup:	27,000 MWd/MTU
Minimum Cooling Time:	5-years
Maximum Lattice Average Initial Enrichment:	See Minimum Boron Loading Below
Minimum Initial Bundle Average Enrichment:	2.0 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 2:	
Maximum Burnup:	35,000 MWd/MTU
Minimum Cooling Time:	8-years
Maximum Lattice Average Initial Enrichment:	See Minimum Boron Loading Below
Minimum Initial Bundle Average Enrichment:	2.65 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 3:	
Maximum Burnup:	37,200 MWd/MTU
Minimum Cooling Time:	6.5-years
Maximum Lattice Average Initial Enrichment:	See Minimum Boron Loading Below
Minimum Initial Bundle Average Enrichment:	3.38 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 4:	
Maximum Burnup:	40,000 MWd/MTU
Minimum Cooling Time:	10-years
Maximum Lattice Average Initial Enrichment:	See Minimum Boron Loading Below
Minimum Initial Bundle Average Enrichment:	3.4 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Minimum Boron Loading	
Lattice Average Enrichment (wt%U-235)	Minimum B-10 Content in Poison Plates(g/cm^2)
4.4	0.029
4.1	0.023
3.7	0.018

Table 1-1d
BWR Fuel Specifications of Intact/Damaged Fuel to be Stored in the Standardized NUHOMS®-61BT DSC

Physical Parameters:	
Fuel Design:	*7x7, 8x8 BWR fuel assemblies manufactured by General Electric or equivalent reload fuel*
Cladding Material:	*Zircaloy*
Fuel Damage:	*Cladding damage in excess of pinhole leaks or hairline cracks shall be stored with Top and Bottom Caps for Failed Fuel. Damaged fuel may only be stored in the 2x2 compartments of the NUHOMS®-61B Canister with a minimum B-10 Content in the Poison Plates of 0.029 g/cm².*
Channels:	*Fuel may be stored with or without fuel channels*
Maximum Assembly Length	*176.2 in*
Maximum Assembly Width	*5.44 in*
Maximum Assembly Weight	*705 lbs*
Radiological Parameters:	
Group 1:	
Maximum Burnup:	*27,000 MWd/MTU*
Minimum Cooling Time:	*5-years*
Maximum Initial Lattice Average Enrichment:	*4.0 wt. % U-235*
Maximum Pellet Enrichment:	*4.4 wt. % U-235*
Minimum Initial Bundle Average Enrichment:	*2.0 wt. % U-235*
Maximum Initial Uranium Content:	*198 kg/assembly*
Maximum Decay Heat:	*300 W/assembly*
Group 2:	
Maximum Burnup:	*35,000 MWd/MTU*
Minimum Cooling Time:	*8-years*
Maximum Initial Lattice Average Enrichment:	*4.0 wt. % U-235*
Maximum Pellet Enrichment:	*4.4 wt. % U-235*
Minimum Initial Bundle Average Enrichment:	*2.65 wt. % U-235*
Maximum Initial Uranium Content:	*198 kg/assembly*
Maximum Decay Heat:	*300 W/assembly*
Group 3:	
Maximum Burnup:	*37,200 MWd/MTU*
Minimum Cooling Time:	*6.5-years*
Maximum Initial Lattice Average Enrichment:	*4.0 wt. % U-235*
Maximum Pellet Enrichment:	*4.4 wt. % U-235*
Minimum Initial Bundle Average Enrichment:	*3.38 wt. % U-235*
Maximum Initial Uranium Content:	*198 kg/assembly*
Maximum Decay Heat:	*300 W/assembly*
Group 4:	
Maximum Burnup:	*40,000 MWd/MTU*
Minimum Cooling Time:	*10-years*
Maximum Initial Lattice Average Enrichment:	*4.0 wt. % U-235*
Maximum Pellet Enrichment:	*4.4 wt. % U-235*
Minimum Initial Bundle Average Enrichment:	*3.4 wt. % U-235*
Maximum Initial Uranium Content:	*198 kg/assembly*
Maximum Decay Heat:	*300 W/assembly*

1.2.3 *24P and 52B* DSC Helium Backfill Pressure

Limit/Specifications: Helium 2.5 psig ± 2.5 psig backfill pressure (stable for 30 minutes after filling).

Applicability: This specification is applicable to *24P and 52B* DSCs *only*.

Objective: To ensure that: (1) the atmosphere surrounding the irradiated fuel is a non-oxidizing inert gas; (2) the atmosphere is favorable for the transfer of decay heat.

Action: If the required pressure cannot be obtained:

1. Confirm that the vacuum drying system and helium source are properly installed.
2. Check and repair or replace the pressure gauge.
3. Check and repair or replace the vacuum drying system.
4. Check and repair or replace the helium source.
5. Check and repair the seal weld on DSC top shield plug.

If pressure exceeds the criterion, release a sufficient quantity of helium to lower the DSC cavity pressure.

Surveillance: No maintenance or tests are required during the normal storage. Surveillance of the pressure gauge is required during the helium backfilling operation.

Bases: The value of 2.5 psig was selected to ensure that the pressure within the DSC is within the design limits during any expected normal and off-normal operating conditions.

1.2.3a 61BT DSC Helium Backfill Pressure

Limit/Specifications: *Helium 2.5 psig ± 1.0 psig backfill pressure (stable for 30 minutes after filling).*

Applicability: *This specification is applicable to 61BT DSC only.*

Objective: *To ensure that: (1) the atmosphere surrounding the irradiated fuel is a non-oxidizing inert gas; (2) the atmosphere is favorable for the transfer of decay heat.*

Action: *If the required pressure cannot be obtained:*

1. *Confirm that the vacuum drying system and helium source are properly installed.*
2. *Check and repair or replace the pressure gauge.*
3. *Check and repair or replace the vacuum drying system.*
4. *Check and repair or replace the helium source.*
5. *Check and repair the seal weld on DSC top shield plug.*

If pressure exceeds the criterion, release a sufficient quantity of helium to lower the DSC cavity pressure.

Surveillance: *No maintenance or tests are required during the normal storage. Surveillance of the pressure gauge is required during the helium backfilling operation.*

Bases: *The value of 2.5 psig was selected to ensure that the pressure within the DSC is within the design limits during any expected normal and off-normal operating conditions.*

1.2.4 *24P and 52B* DSC Helium Leak Rate of Inner Seal Weld

Limit/Specification:

$\leq 1.0 \times 10^{-4}$ atm · cubic centimeters per second (atm · cm^3/s) at the highest DSC limiting pressure.

Applicability: This specification is applicable to the inner top cover plate seal weld of *the 24P and 52B* DSCs *only*.

Objective:

1. To limit the total radioactive gases normally released by each canister to negligible levels. Should fission gases escape the fuel cladding, they will remain confined by the DSC confinement boundary.

2. To retain helium cover gases within the DSC and prevent oxygen from entering the DSC. The helium improves the heat dissipation characteristics of the DSC and prevents any oxidation of fuel cladding.

Action: If the leak rate test of the inner seal weld exceeds 1.0×10^{-4} (atm · cm^3/s):

1. Check and repair the DSC drain and fill port fittings for leaks.

2. Check and repair the inner seal weld.

3. Check and repair the inner top cover plate for any surface indications resulting in leakage.

Surveillance: After the welding operation has been completed, perform a leak test with a helium leak detection device.

Bases: If the DSC leaked at the maximum acceptable rate of 1.0×10^{-4} atm · cm^3/s for a period of 20 years, about 63,100 cc of helium would escape from the DSC. This is about 1% of the 6.3×10^6 cm^3 of helium initially introduced in the DSC. This amount of leakage would have a negligible effect on the inert environment of the DSC cavity. (Reference: American National Standards Institute, ANSI N14.5-1987, "For Radioactive Materials—Leakage Tests on Packages for Shipment," Appendix B3).

1.2.4a 61BT DSC Helium Leak Rate of Inner Seal Weld

Limit/Specification:

$\leq$1.0 x 10^{-7} atm · cubic centimeters per second (atm · cm^3/s) at the highest DSC limiting pressure.

Applicability: *This specification is applicable to the inner top cover plate seal weld of 61BT DSC only.*

Objective:

1. *To demonstrate that the top cover plate to be "leak tight", as defined in "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials," ANSI N14.5 - 1997.*

2. *To retain helium cover gases within the DSC and prevent oxygen from entering the DSC. The helium improves the heat dissipation characteristics of the DSC and prevents any oxidation of fuel cladding.*

Action: *If the leak rate test of the inner seal weld exceeds 1.0x10^{-7} (atm · cm^3/s):*

1. *Check and repair the DSC drain and fill port fittings for leaks.*

2. *Check and repair the inner seal weld.*

3. *Check and repair the inner top cover plate for any surface indications resulting in leakage.*

Surveillance: *After the welding operation has been completed, perform a leak test with a helium leak detection device.*

Bases: *The 61BT DSC will maintain an inert atmosphere around the fuel and radiological consequences will be negligible, since it is designed and tested to be leak tight..*

1.2.7 HSM Dose Rates

Limit/Specification:

Dose rates at the following locations shall be limited to levels which are less than or equal to:

a. 400 mrem/hr at 3 feet from the HSM surface.

b. Outside of HSM door on center line of DSC 100 mrem/hr.

c. End shield wall exterior 20 mrem/hr.

Applicability: This specification is applicable to all HSMs which contain a loaded DSC.

Objective: The dose rate is limited to this value to ensure that the cask (DSC) has not been inadvertently loaded with fuel not meeting the specifications in Section 1.2.1 and to maintain dose rates as-low-as-is-reasonably achievable (ALARA) at locations on the HSMs where surveillance is performed, and to reduce off-site exposures during storage.

Action:

a. If specified dose rates are exceeded, the following actions should be taken:

   1. Ensure that the DSC is properly positioned on the support rails.

   2. Ensure proper installation of the HSM door.

   3. Ensure that the required module spacing is maintained.

   4. Confirm that the spent fuel assemblies contained in the DSC conform to the specifications of Section 1.2.1.

   5. Install temporary or permanent shielding to mitigate the dose to acceptable levels in accordance with 10 CFR Part 20, 10 CFR 72.104(a), and ALARA.

b. Submit a letter report to the NRC within 30 days summarizing the action taken and the results of the surveillance, investigation and findings. The report must be submitted using instructions in 10 CFR 72.4 with a copy sent to the administrator of the appropriate NRC regional office.

Surveillance: The HSM and ISFSI shall be checked to verify that this specification has been met after the DSC is placed into storage and the HSM door is closed.

Basis: The basis for this limit is the shielding analysis presented in Section 7.0 and Appendix J *and Appendix* K of the SAR. The specified dose rates provide as-low-as-is-reasonably-achievable on-site and off-site doses in accordance with 10 CFR Part 20 and 10 CFR 72.104(a).1.2.11

1.2.11 Transfer Cask Dose Rates

Limit/Specification:

Dose rates from the transfer cask shall be limited to levels which are less than or equal to:

a. 200 mrem/hr at 3 feet with water in the DSC cavity.

b. 500 mrem/hr at 3 feet without water in the DSC cavity.

Applicability: This specification is applicable to the transfer cask containing a loaded DSC.

Objective: The dose rate is limited to this value to ensure that the DSC has not been inadvertently loaded with fuel not meeting the specifications in Section 1.2.1 and to maintain dose rates as-low-as-is-reasonably achievable during DSC transfer operations.

Action: If specified dose rates are exceeded, place temporary shielding around affected areas of transfer cask and review the plant records of the fuel assemblies which have been placed in DSC to ensure they conform to the fuel specifications of Section 1.2.1. Submit a letter report to the NRC within 30 days summarizing the action taken and the results of the surveillance, investigation and findings. The report must be submitted using instructions in 10 CFR 72.4 with a copy sent to the administrator of the appropriate NRC regional office.

Surveillance: The dose rates should be measured as soon as possible after the transfer cask is removed from the spent fuel pool.

Basis: The basis for this limit is the shielding analysis presented in Section 7.0, *Appendix J and Appendix K* of the SAR.

1.2.15 Boron Concentration in the DSC Cavity Water (24-P Designs Only)

Limit/Specification:

The DSC cavity shall be filled only with water having a boron concentration equal to, or greater than 2,000 ppm.

Applicability: This limit applies only to the standardized NUHOMS®-24P design. No boration in the cavity water is required for the standardized NUHOMS®-52B *or NUHOMS®-61BT* system since *these* systems use fixed absorber plates.

Objective: To ensure a subcritical configuration is maintained in the case of accidental loading of the DSC with unirradiated fuel.

Action: If the boron concentration is below the required weight percentage concentration (gm boron/10^6 gm water), add boron and re-sample, and test the concentration until the boron concentration is shown to be greater than that required.

Surveillance: Written procedures shall be used to independently determine (two samples analyzed by different individuals) the boron concentration in the water used to fill the DSC cavity.

1. Within 4 hours before insertion of the first fuel assembly into the DSC, the dissolved boron concentration in water in the spent fuel pool, and in the water that will be introduced in the DSC cavity, shall be independently determined (two samples chemically analyzed by two individuals).

2. Within 4 hours before flooding the DSC cavity for unloading the fuel assemblies, the dissolved boron concentration in water in the spent pool, and in the water that will be introduced into the DSC cavity, shall be independently determined (two samples analyzed chemically by two individuals).

3. The dissolved boron concentration in the water shall be reconfirmed at intervals not to exceed 48 hours until such time as the DSC is removed from the spent fuel pool or the fuel has been removed from the DSC.

Bases: The required boron concentration is based on the criticality analysis for an accidental misloading of the DSC with unburned fuel, maximum enrichment, and optimum moderation conditions.

1.2.16 Provision of TC Seismic Restraint Inside the Spent Fuel Pool Building as a Function of Horizontal Acceleration and Loaded Cask Weight

Limit/Specification:

Seismic restraints shall be provided to prevent overturning of a loaded TC during a seismic event if a certificate holder determines that the horizontal acceleration is 0.40 g or greater and the fully loaded TC weight is less than 190 kips. The determination of horizontal acceleration acting at the center of gravity (CG) of the loaded TC must be based on a peak horizontal ground acceleration at the site, but shall not exceed 0.25 g.

Applicability: This condition applies to all TCs which are subject to horizontal accelerations of 0.40 g or greater.

Objective: To prevent overturning of a loaded TC inside the spent fuel pool building.

Action: Determine what the horizontal acceleration is for the TC and determine if the cask weight is less than 190 kips.

Surveillance: Determine need for TC restraint before any operations inside the spent fuel pool building.

Bases: Calculation of overturning and restoring *moments*.

1.2.17 61BT DSC Vacuum Drying Duration Limit

Limit/Specifications: *Time limit for duration of Vacuum Drying is 96 hrs after completion of 61BT DSC draining.*

Applicability: *This specification is only applicable to a 61BT DSC with greater than 17.6 kw heat load.*

Objective: *To ensure that 61BT DSC basket structure does not exceed 800^0 F.*

Action:

1. *If the DSC vacuum drying pressure limit of Technical Specification 1.2.2 cannot be achieved at 72 hours after completion of DSC draining, the DSC must be backfilled with 0.1 atm or greater helium pressure within 24 hours.*

2. *Determine the cause of failure to achieve the vacuum drying pressure limit as defined in Technical Specification 1.2.2.*

3. *Initiate vacuum drying after actions in Step 2 are completed or unload the DSC within 30 days.*

Surveillance: *No maintenance or tests are required during the normal storage. Monitoring of the time duration during the vacuum drying operation is required .*

Bases: *The time limit of 96 hours was selected to ensure that the temperature within the DSC is within the design limits during vacuum drying.*

Table 1.3.1

Summary of Surveillance and Monitoring Requirements

Surveillance or Monitoring	Period	Reference Section
1. Fuel Specification	PL	1.2.1
2. DSC Vacuum Pressure During Drying	L	1.2.2
3. DSC Helium Backfill Pressure	L	1.2.3 *or* *1.2.3a*
4. DSC Helium Leak Rate of Inner Seal Weld	L	1.2.4 *or* *1.2.4a*
5. DSC Dye Penetrant Test of Closure Welds	L	1.2.5
6. *Deleted*	-	-
7. HSM Dose Rates	L	1.2.7
8. HSM Maximum Air Exit Temperature	24 hrs	1.2.8
9. TC Alignment with HSM	S	1.2.9
10. DSC Handling Height Outside Spent Fuel Pool Building	AN	1.2.10
11. Transfer Cask Dose Rates	L	1.2.11
12. Maximum DSC Surface Contamination	L	1.2.12
13. TC/DSC Lifting Heights as a Function of Low Temperature and Location	L	1.2.13
13. TC/DSC Lifting Heights as a Function of Low Temperature and Location	L	1.2.13

<u>Legend</u>

PL Prior to loading
L During loading and prior to movement to HSM pad
24 hrs Time following DSC insertion into HSM
S Prior to movement of DSC to or from HSM
AN As necessary
D Daily (24 hour frequency)

14. TC/DSC Transfer Operations at High Ambient Temperatures	L	1.2.14
15. Boron Concentration in DSC Cavity Water (24-P Designs Only)	PL	1.2.15
16. Provision of TC Seismic Restraint Inside the Spent Fuel Pool Building as a Function of Horizontal Acceleration and Loaded Cask Weight	PL	1.2.16
17. Visual Inspection of HSM Air Inlets and Outlets	D	1.3.1
18. HSM Thermal Performance	D	1.3.2
19 Vacuum Drying Limits	*L*	*1.2.17*

Legend

PL Prior to loading
L During loading and prior to movement to HSM pad
24 hrs Time following DSC insertion into HSM
S Prior to movement of DSC to or from HSM
AN As necessary
D Daily (24 hour frequency)

K.1 General Discussion

This Amendment to the Certificate of Compliance (COC) 72-1004 addresses the Important to Safety aspects of -storing spent fuel in the NUHOMS®-61BT System. The NUHOMS®-61BT System consists of a NUHOMS®-61BT DSC stored in a NUHOMS® Horizontal Storage Module (HSM) and transferred in a OS 197 Transfer Cask (TC). There is no change to the HSM or the TC as described in NUHOMS® C of C 72-1004. The format follows the guidance provided in NRC Regulatory Guide 3.61 [1.1]. A separate analysis will be submitted to address the safety related aspects of transporting spent fuel in the NUHOMS®-61BT Dry Shielded Canister (DSC) in accordance with 10CFR71 [1.3].

The NUHOMS®-61BT System provides confinement, shielding, criticality control and passive heat removal independent of any other facility structures or components. The NUHOMS®-61BT DSC also maintains structural integrity of the fuel during storage.

K.1.1 Introduction

The NUHOMS® System provides a modular canister based spent fuel storage and transport system. The system includes Dry Shielded Canisters (DSCs), Horizontal Storage Modules (HSMs); and the OS-197 Transfer Cask. Currently, the 24P and 52B DSCs are authorized for storage under COC 72-1004. This Amendment adds the 61BT DSC. Only those features that are being revised or added to the NUHOMS® system are addressed and evaluated in this Amendment. The HSM and OS-197 Transfer Cask remain unchanged. The NUHOMS®-61BT DSC is similar to the existing DSCs with the following exceptions:

- The canister shell thickness is reduced from 0.625 inches to 0.5 inches.
- The canister has been upgraded to provide a leak tight confinement.
- The basket represents a new design.
- The thickness of the top and bottom shield plug is reduced slightly to accommodate the new basket design.

The NUHOMS®-61BT DSC is designed to store 61 intact, or up to 16 damaged and remainder intact, for a total of 61, standard Boiling Water Reactor (BWR) fuel assemblies with or without fuel channels. The NUHOMS®-61BT DSC is designed for a maximum heat load of 18.3 kW or 0.3 kW/assembly. The fuel which may be stored in the NUHOMS®-61BT DSC is presented in Section K.2.0.

K.1.2 General Description of the NUHOMS®-61BT DSC

K.1.2.1 NUHOMS®-61BT DSC Characteristics

Each NUHOMS®-61BT DSC consists of a fuel basket and a canister body (shell, canister inner bottom and top cover plates and shield plugs). A sketch of the 61BT DSC is shown in Figure K.1-1. A set of reference drawings is presented in Section K.1.5. Dimensions and the estimated weight of the NUHOMS®-61BT DSC are shown in Table K.1-1. The NUHOMS®-61BT DSC shell thickness is 0.50 inches instead of 0.625 inches as used for the NUHOMS®-24P or –52B DSC designs. The bottom and top shield plugs are 5.0 and 7.0 inches respectively as compared to the 5.75 and 8.0 inches used for the NUHOMS®-52B DSC designs. The materials used to fabricate the DSC are shown in the Parts List on Drawing NUH-61B-1065.

The confinement vessel for the NUHOMS®-61BT DSC consists of a shell which is a welded, stainless steel cylinder with an integrally-welded, stainless steel bottom closure assembly; and a stainless steel top closure assembly, which includes the vent and drain system.

There are no penetrations through the confinement vessel. The draining and venting systems are covered by the seal welded outer top closure plate and vent port plug. To preclude air in-leakage, the canister cavity is pressurized above atmospheric pressure with helium. The NUHOMS®-61BT DSC is designed and tested to meet the leak tight criteria of ANSI N14.5-1997.

The basket structure consists of assemblies of stainless steel fuel compartments held in place by basket rails and holddown rings. The four and nine compartment assemblies are held together by welded stainless steel boxes wrapped around the fuel compartments, which also retain the neutron poison plates between the compartments in the assemblies. The borated aluminum or boron carbide/aluminum metal matrix composite plates (neutron poison plates) provide the necessary criticality control and provide the heat conduction paths from the fuel assemblies to the cask cavity wall. This method of construction forms a very strong structure of compartment assemblies which provide for storage of 61 fuel assemblies. The minimum open dimension of each fuel compartment is 6.0 in. x 6.0 in., which provides clearance around the fuel assemblies.

There are three NUHOMS®-61BT DSC basket types, A, B, and C, as shown on Drawing NUH-61B-1065. The types are identical with the exception of the minimum B-10 content of the poison plates. The maximum lattice average enrichment of the fuel assemblies allowed by basket type is given in Table K.2-4. Damaged fuel is only stored in Type C baskets, in four corner compartment assemblies with endcaps installed on the respective damaged fuel compartments.

During dry storage of the spent fuel in the NUHOMS®-61BT System, no active systems are required for the removal and dissipation of the decay heat from the fuel. The NUHOMS®-61BT DSC is designed to transfer the decay heat from the fuel to the basket, from the basket to the canister body and ultimately to the ambient via HSM or Transfer Cask.

Each canister is identified by a Mark Number, NUHOMS®-61BT DSC -XX, Type Y. where XX is a sequential number corresponding to a specific canister, and Y refers to the basket type. Each canister is also marked with the patent number.

K.1.2.2 Operational Features

K.1.2.2.1 General Features

The NUHOMS®-61BT DSC is designed to safely store 61 intact, or up to 16 damaged and remainder intact, for a total of 61, standard BWR fuel assemblies with or without fuel channels. The NUHOMS®-61BT DSC is designed to maintain the fuel cladding temperature below 649°F (343° C) during storage. It is also designed to maintain the fuel cladding temperature below 1058°F (570° C) during short-term accident conditions, short-term off-normal conditions and fuel transfer operations.

The criticality control features of the NUHOMS®-61BT DSC are designed to maintain the neutron multiplication factor k-effective less than the upper subcritical limit equal to 0.95 minus benchmarking bias and modeling bias under all conditions.

K.1.2.2.2 Sequence of Operations

The sequence of operations to be performed in loading fuel into the NUHOMS®-61BT DSC is presented in Chapter K.8. The operations are the same as presented in the existing CSAR, with the exception of the handling of the OS-197 Transfer Cask with NUHOMS®-61BT DSC using a 100-ton rated crane.

K.1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

K.1.2.2.3.1 Criticality Prevention

Criticality is controlled by geometry and by utilizing neutron poison in the fuel basket. These features are only necessary during the loading and unloading operations that occur in the loading pool (underwater). During storage, with the DSC cavity dry and sealed from the environment, criticality control measures within the installation are not necessary because of the low reactivity of the fuel in the dry NUHOMS®-61BT DSC and the assurance that no water can enter the DSC cavity during storage.

K.1.2.2.3.2 Chemical Safety

There are no chemical safety hazards associated with operations of the NUHOMS®-61BT System.

K.1.2.2.3.3 Operation Shutdown Modes

The NUHOMS®-61BT DSC is a totally passive system so that consideration of operation shutdown modes is unnecessary.

K.1.2.2.3.4 Instrumentation

No change.

K.1.2.2.3.5 Maintenance Techniques

No change.

K.1.2.3 Cask Contents

The NUHOMS®-61BT DSC is designed to store 61 intact, or up to 16 damaged and remainder intact, for a total of 61, standard Boiling Water Reactor (BWR) fuel assemblies with or without fuel channels. The NUHOMS®-61BT DSC is designed for a maximum heat load of 18.3 kW or 0.3 kW/assembly. The fuel which may be stored in the NUHOMS®-61BT DSC is presented in Table K.2-3.

Chapter K.5 provides the shielding analysis. Chapter K.6 covers the criticality safety of the NUHOMS®-61BT DSC and its contents, listing material densities, moderator ratios, and geometric configurations.

K.1.3 Identification of Agents and Contractors

Transnuclear West, Inc. (TNW), provides the design, analysis, licensing support and quality assurance for the NUHOMS®-61BT System. Fabrication of the NUHOMS®-61BT System cask is done by one or more qualified fabricators under TNW's quality assurance program. TNW's quality assurance program is described in Chapter K.13. This program is written to satisfy the requirements of 10 CFR 72, Subpart G and covers control of design, procurement, fabrication, inspection, testing, operations and corrective action. Experienced TNW operations personnel provide training to utility personnel prior to first use of the NUHOMS®-61BT System and prepare generic operating procedures.

Managerial and administrative controls, which are used to ensure safe operation of the casks, are provided by the host utility. NUHOMS®-61BT System operations and maintenance are performed by utility personnel. Decommissioning activities will be performed by utility personnel in accordance with site procedures.

Transnuclear West, Inc. provides specialized services for the nuclear fuel cycle that support transportation, storage and handling of spent nuclear fuel, radioactive waste and other radioactive materials. TNW is the holder of Certificate of Compliance (72-1004).

K.1.4 Generic Cask Arrays

No change.

K.1.5 Supplemental Data

The following Transnuclear West drawings are enclosed:

1. NUHOMS® -61B Transportable Canister for BWR Fuel General Arrangement, Drawing NUH-61B-1060, Revision 0.

2. NUHOMS® -61B Transportable Canister for BWR Fuel Shell Assembly, Drawing NUH-61B-1061, Revision 0.

3. NUHOMS® -61B Transportable Canister for BWR Fuel Canister Details, Drawing NUH-61B-1062, Revision 0.

4. NUHOMS® -61B Transportable Canister for BWR Fuel Basket Assembly, Drawing NUH-61B-1063, Revision 0.

5. NUHOMS® -61B Transportable Canister for BWR Fuel Basket Details, Drawing NUH-61B-1064, Revision 0.

6. NUHOMS® -61B Transportable Canister for BWR Fuel Parts List, Drawing NUH-61B-1065, Revision 0.

7. NUHOMS® -61B Transportable Canister Top & Bottom Cap Details for Failed BWR Fuel, Drawing NUH-61B-1066, Revision 0.

K.1.6 References

1.1 US Nuclear Regulatory Commission, Regulatory Guide 3.61, Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask, February, 1989.

1.2 10CFR72, Rules and Regulations, Title 10, Chapter 1, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste".

1.3 10CFR71, Rules and Regulations, Title 10, Chapter 1, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Packaging and Transportation of Radioactive Material".

Table K.1-1
Nominal Dimensions and Weight of the NUHOMS®-61BT DSC

Overall length (with grapple, in)	199.7
Outside diameter (in)	67.25
Cavity diameter (in)	66.25
Cavity length (in)	179.3
Nominal DSC weight:	
Loaded on storage pad (kips)	88.5

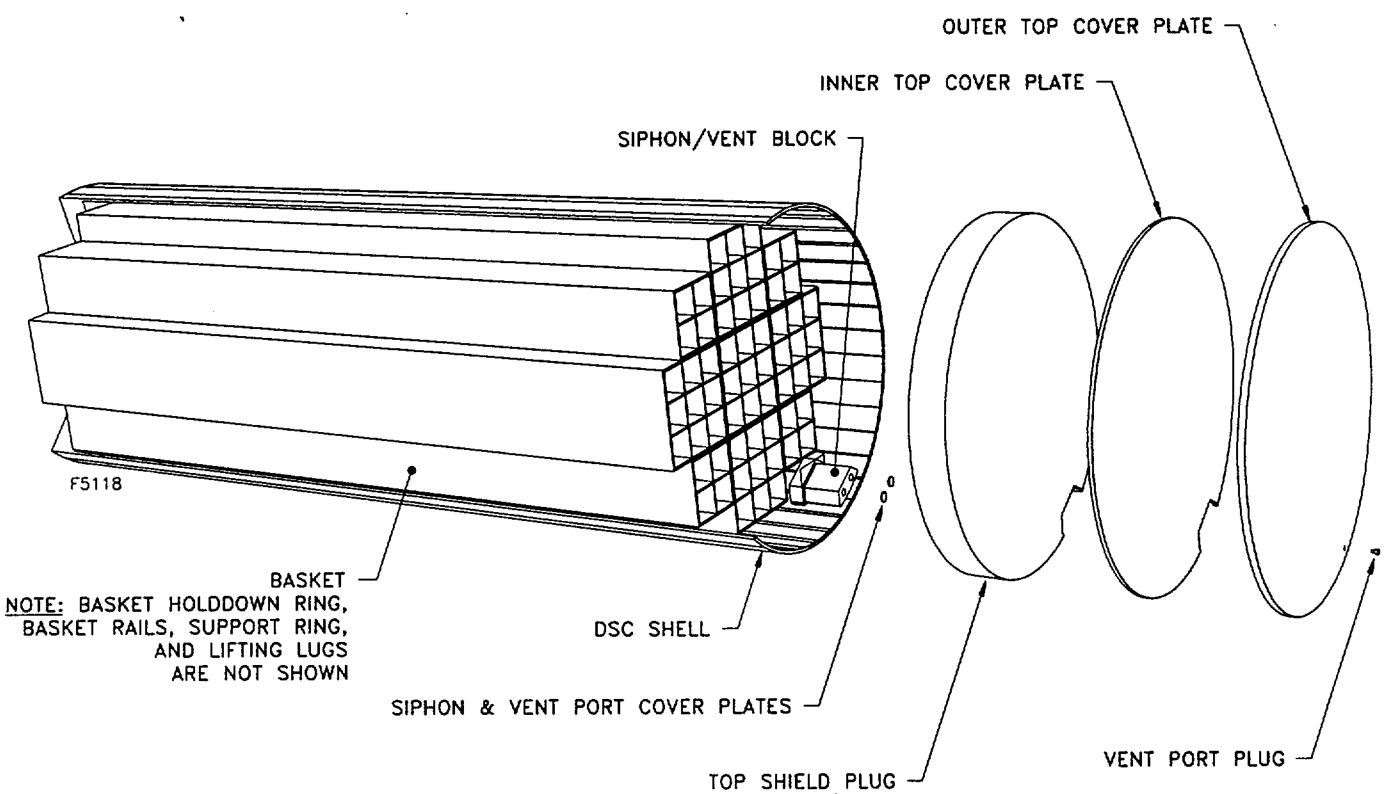


Figure K.1-1
NUHOMS® -61BT DSC Components

K.2 Principal Design Criteria

This section provides the principal design criteria for the NUHOMS®-61BT System. The NUHOMS®-61BT Dry Shielded Canister (DSC) is handled, transferred and stored in the same manner as the existing NUHOMS®-52B DSC. There is no change to the NUHOMS® OS-197 Transfer Cask or the standard NUHOMS® Horizontal Storage Module (HSM). Only those principal design criteria that have changed from the existing CSAR, Chapter 3, are described in this chapter. Section K.2.1 presents a general description of the spent fuel to be stored. Section K.2.2 provides the design criteria for environmental conditions and natural phenomena. This section contains an assessment of the local damage due to the design basis environmental conditions and natural phenomena and the general loadings and design parameters used for analysis in subsequent chapters. Section K.2.3 provides a description of the systems which have been designated as important to safety. Section K.2.4 discusses decommissioning considerations. Section K.2.5 summarizes the NUHOMS®-61BT DSC design criteria.

K.2.1 Spent Fuel To Be Stored

The NUHOMS®-61BT DSC is designed to store 61 intact, or up to 16 damaged and the remainder intact, for a total of 61, standard BWR fuel assemblies with or without fuel channels. The NUHOMS®-61BT DSC can store intact BWR fuel assemblies with the characteristics described in Table K.2-1, or damaged and intact BWR fuel assemblies with the characteristics described in Table K.2-2, which include a variety of cooling times, enrichment and maximum bundle average burnup. The NUHOMS®-61BT DSC may store BWR fuel assemblies with a maximum decay heat of 300 watts/assembly, or a total of 18.3 kW. The NUHOMS®-61BT DSC is inserted and backfilled with helium at the time of loading. The maximum fuel assembly weight with channel is 705 lbs.

Calculations were performed to determine the fuel assembly type which was most limiting for each of the analyses including shielding, criticality, heat load and confinement. The fuel assemblies considered are listed in Table K.2-3. It was determined that the GE 7x7 is the enveloping fuel design for the shielding source term calculation. However, for criticality safety, the GE 10x10 assembly is the most reactive, and is evaluated for configurations that bound all normal, off-normal and accident conditions.

The NUHOMS®-61BT DSC has three basket configurations, based on the boron content in the poison plates. The maximum lattice average enrichment authorized for Type A, B and C NUHOMS®-61BT DSCs is 3.7, 4.1 and 4.4 weight percent (wt. %) U-235, respectively.

Intact BWR fuel assemblies may be stored in any of the three NUHOMS®-61BT DSC Types provided the loading meets the maximum lattice average enrichment limit for the NUHOMS®-61BT DSC type, as given on Table K.2-4. Damaged BWR fuel assemblies may only be stored in Type C NUHOMS®-61BT DSCs with endcaps installed on each four compartment assembly where a damaged fuel assembly is stored.

Fuel assemblies with various combinations of burnup, enrichment and cooling time can be stored in the NUHOMS®-61BT DSC as long as the fuel assembly parameters fall within the design limits specified in Table K.2-1 or Table K.2-2, and Table K.2-4.

For calculating the maximum internal pressure in the NUHOMS®-61BT DSC, it is assumed that 1% of the fuel rods are damaged for normal conditions, up to 10% of the fuel rods are damaged for off normal conditions, and 100% of the fuel rods will be damaged following a design basis accident event. A minimum of 100% of the fill gas and 30% of the fission gases (e.g., H-3, Kr and Xe) within the ruptured fuel rods are assumed to be available for release into the DSC cavity, consistent with NUREG-1536 [2.1].

The maximum design basis internal pressures for the NUHOMS®-61BT DSC are 10, 20 and 65 psig for normal, off-normal and accident conditions of storage, respectively.

K.2.1.1 General Operating Functions

No change.

K.2.2 Design Criteria for Environmental Conditions and Natural Phenomena

The NUHOMS®-61BT DSC is handled and stored in the same manner as the existing NUHOMS®-52B System. The environmental conditions and natural phenomena are the same as described in the existing CSAR, Chapter 3. Updated criteria are given in the applicable section.

K.2.2.1 Tornado Wind and Tornado Missiles

No change.

K.2.2.2 Water Level (Flood) Design

No change.

K.2.2.3 Seismic Design

No change.

K.2.2.4 Snow and Ice Loading

No change.

K.2.2.5 Combined Load Criteria

The NUHOMS®-61BT System is subjected to the same loads as the existing NUHOMS®-24P or-52B System. The criteria applicable to the HSM and the OS-197 Transfer Cask are the same as those found in the existing CSAR, Chapter 3. The criteria applicable to the NUHOMS®-61BT DSC are found in the following subsections.

K.2.2.5.1 NUHOMS®–61BT DSC Structure Design Criteria

The NUHOMS®-61BT DSC is designed using the ASME Boiler and Pressure Vessel Code [2.2] criteria given in the existing CSAR, Chapter 3, except as noted in the following sections. A summary of the NUHOMS®-61BT DSC load combinations is presented in Table K.2-5.

K.2.2.5.1.1 NUHOMS®–61BT DSC Shell Stress Limits

The stress limits for the NUHOMS®-61BT DSC shell are taken from the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-3200 [2.2] for normal condition loads (Level A) and Appendix F 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 and D service loading conditions are given in Table K.2-6. Local yielding is permitted at the point of contact where the Level D load is applied. If elastic stress limits cannot be met, the plastic system analysis approach and acceptance criteria of Appendix F of ASME Section III shall be used.

- Reference to ASME, Section III, Subsection NB, Paragraph NB-3223 and 3224 for Level B and Level C stress limits.

- The allowable stress intensity value, S_m, as defined by the Code shall be taken at the temperature calculated for each service load condition.

K.2.2.5.1.2 NUHOMS®–61BT DSC Basket Stress Limits

The basket fuel compartment 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 primary stress analyses of the basket for Level A (Normal Service) and sustained Level D conditions do not take credit for the neutron poison plates except for through thickness compression. The poison plate strength is, however, considered when determining secondary stresses in the stainless steel.

Normal Conditions

- The basis for the stainless steel basket assembly stress allowables is the ASME Code, Section III, Subsection NG. The primary membrane stress intensity and membrane plus bending stress intensities are limited to S_m (S_m is the code allowable stress intensity) and 1.5 S_m, respectively, for Level A (Normal Service) load combinations. The average primary shear stress is limited to 0.6 S_m.

- The ASME Code provides a basic $3S_m$ limit on primary plus secondary stress intensity for Level A conditions. That limit is specified to prevent ratcheting of a structure under cyclic loading and to provide controlled linear strain cycling in the structure so that a valid fatigue analysis can be performed.

- Reference to ASME Section III, Subsection NG, paragraph NG-3223 and NG-3224 for Level B and Level C stress limits.

Accident Conditions

- 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 (P_m) is limited to the smaller of $2.4S_m$ or $0.7S_u$ and membrane plus bending stress intensities are limited to the smaller of $3.6S_m$ or $1.0S_u$. The average 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 $0.7S_u$ and the maximum stress intensity at any location (P_l or $P_l + P_b$) shall not exceed 0.9 S_u.

- The fuel compartment walls and basket rails, when subjected to compressive loadings, are also evaluated against ASME Code rules for component supports to ensure that buckling will not occur. The acceptance criteria (allowable buckling loads) are taken from ASME Code, Section III, Appendix F, paragraph F-1341.3, Collapse Load. The allowable buckling load is equal to 100% of the calculated plastic analysis collapse load or 100% of the test collapse load.

- The stress and load limits for the basket are summarized in Table K.2-7.

K.2.3 Safety Protection Systems

K.2.3.1 General

The NUHOMS®-61BT DSC is designed to provide storage of spent fuel for at least 40 years. The cask cavity pressure is always above atmospheric during the storage period as a precaution against the in-leakage of air which could be harmful to the fuel. Since the confinement vessel consists of a steel cylinder with an integrally-welded bottom closure, and a seal welded top closure that is verified to be leak tight after loading, the cavity gas cannot escape.

Only those features that are not addressed in the existing CSAR, Chapter 3, or have been revised, are addressed in this Section. Those features include the thermal and nucleonic performance of the poison plates, and their acceptance. Components of the NUHOMS®-61BT DSC that are "Important to Safety" and "Not Important to Safety" are listed in Table K.2-8.

K.2.3.2 Protection By Multiple Confinement Barriers and Systems

The NUHOMS®-61BT DSC provides a leak tight confinement of the spent fuel. Although similar to the existing -52B DSC, sealing of the NUHOMS®-61BT DSC involves leak testing in accordance with ANSI N14.5 [2.3] after loading and sealing the canister, as described in Section K.9.

The NUHOMS®-61BT DSC poison plates are required to meet the minimum uniform boron concentration limits of Table K.2-4 in support of criticality safety. A detailed acceptance program for the neutron poison material is given in Section K.9. The program also requires that the plates be tested to verify they meet the minimum thermal conductivity limits given in Section K.4.

K.2.3.3 Protection By Equipment and Instrumentation Selection

No change.

K.2.3.4 Nuclear Criticality Safety

K.2.3.4.1 Control Methods for Prevention of Criticality

The design criterion for criticality is that an upper subcritical limit (USL) of 0.95 minus benchmarking bias and modeling bias will be maintained for all postulated arrangements of fuel within the DSC. The intact fuel assemblies and the damaged fuel assemblies are assumed to stay within their basket compartment based on the DSC and basket geometry.

The control method used to prevent criticality is incorporation of poison material in the basket material and favorable geometry. The quantity and distribution of boron in the poison material is controlled by specific manufacturing and acceptance criteria of the poison plates. The acceptance of the plates is described in Section K.9.

The basket has been designed to assure an ample margin of safety against criticality under the conditions of fresh fuel in a DSC flooded with fresh water. The method of criticality control is in accordance with the requirements of 10CFR72.124.

The criticality analyses are described in Section K.6.

K.2.3.4.2 Error Contingency Criteria

Provision for error contingency is built into the criterion used in Section K.2.3.4.1 above. The criterion used in the criticality analysis is common practice for licensing submittals. Because conservative assumptions are made in modeling, it is not necessary to introduce additional contingency for error.

K.2.3.4.3 Verification Analysis-Benchmarking

The verification analysis-benchmarking used in the criticality safety analysis is described in Section K.6.

K.2.3.5 Radiological Protection

No change.

K.2.3.6 Fire and Explosion Protection

No change.

K.2.4 Decommissioning Considerations

No change.

K.2.5 Summary of NUHOMS®-61BT DSC Design Criteria

The additional principal design criteria for the NUHOMS®-61BT DSC are presented in Table K.2-1. The NUHOMS®-61BT DSC is designed to store 61 intact, or up to 16 damaged and the remainder intact, for a total of 61, standard BWR fuel assemblies with or without fuel channels with assembly average burnup, initial enrichment and cooling time as described in Tables K.2-1, K.2-2 and K.2-4.

The maximum total heat generation rate of the stored fuel is limited to 0.3 kW per fuel assembly and 18.3 kW per NUHOMS®-61BT DSC in order to keep the maximum fuel cladding temperature below the limit necessary to ensure cladding integrity for 40 years storage [2.4]. The fuel cladding integrity is assured by the NUHOMS®-61BT DSC and basket design which limits fuel cladding temperature and maintains a nonoxidizing environment in the cask cavity [2.5], as described in Section K.4.

The NUHOMS®-61BT DSC (shell and closure) is designed and fabricated to the maximum practicable extent as a Class I component in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-3200.

The NUHOMS®-61BT DSC is designed to maintain a subcritical configuration during loading, handling, storage and accident conditions. Poison materials in the fuel basket are employed to maintain the upper subcritical limit of 0.9414. The basket is designed and fabricated to the maximum practicable extent in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NG, Article NG-3200.

The NUHOMS®-61BT DSC design, fabrication and testing are covered by Transnuclear West's Quality Assurance Program which conforms to the criteria in Subpart G of 10CFR72.

The NUHOMS®-61BT DSC is designed to withstand the effects of severe environmental conditions and natural phenomena such as earthquakes, tornadoes, lightning and floods. Section K.11 describes the NUHOMS®-61BT DSC behavior under these accident conditions.

K.2.6 References

2.1 NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," 1997.

2.2 American Society of Mechanical Engineers, ASME Boiler And Pressure Vessel Code, Section III, Division 1 - Subsections NB and NG, 1998 edition including 1999 addenda.

2.3 ANSI N14.5-1997, "Leakage Tests on Packages for Shipment," February 1998.

2.4 Levy, et. al., "Recommended Temperature Limits for Dry Storage of Spent Light Water Reactor Zircaloy - Clad Fuel Rods in Inert Gas," Pacific Northwest Laboratory, PNL-6189, 1987.

2.5 Johnson, et. al., "Technical Basis for Storage of Zircaloy-Clad Spent Fuel in Inert Gases," PNL-4835, Pacific Northwest Laboratory, Richland, Wash., Sept. 1983.

Table K.2-1
Intact BWR Fuel Assembly Characteristics

<u>PHYSICAL PARAMETERS:</u> Fuel Design:	7x7, 8x8, 9x9, or 10x10 BWR fuel assemblies manufactured by General Electric or equivalent reload fuel
Cladding Material:	Zircaloy
Fuel Damage:	Cladding damage in excess of pinhole leaks or hairline cracks is not authorized to be stored as "Intact BWR Fuel".
Channels: <u>RADIOLOGICAL PARAMETERS</u>[1]: *Group 1:* Maximum Burnup:	Fuel may be stored with or without fuel channels 27,000 MWd/MTU
Minimum Cooling Time:	5-years
Maximum Initial Enrichment:	See Table K.2-4
Minimum Initial Bundle Average Enrichment:	2.0 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 2: Maximum Burnup:	35,000 MWd/MTU
Minimum Cooling Time:	8-years
Maximum Initial Enrichment:	See Table K.2-4
Minimum Initial Bundle Average Enrichment:	2.65 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 3: Maximum Burnup:	37,200 MWd/MTU
Minimum Cooling Time:	6.5-years
Maximum Initial Enrichment:	See Table K.2-4
Minimum Initial Bundle Average Enrichment:	3.38 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 4: Maximum Burnup:	40,000 MWd/MTU
Minimum Cooling Time:	10-years
Maximum Initial Enrichment:	See Table K.2-4
Minimum Initial Bundle Average Enrichment:	3.4 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly

[1] Fuel assemblies fully complying with any of the following groups of parameters are suitable for storage in the NUHOMS®-61BT DSC.

Table K.2-2
Damaged BWR Fuel Assemblies Characteristics

PHYSICAL PARAMETERS: Fuel Design:	7x7, 8x8 BWR fuel assemblies manufactured by General Electric or equivalent reload fuel
Cladding Material:	Zircaloy
Fuel Damage:	Cladding damage in excess of pinhole leaks or hairline cracks shall be stored with Top and Bottom Caps for Damaged Fuel. Damaged fuel may only be stored in the four compartment assemblies of the NUHOMS®-61BT DSC with a minimum B-10 Content in the Poison Plates of 0.029 g/cm^2.
Channels:	Fuel may be stored with or without fuel channels
RADIOLOGICAL PARAMETERS[2]: *Group 1:* Maximum Burnup:	27,000 MWd/MTU
Minimum Cooling Time:	5-years
Maximum Initial Lattice Average Enrichment:	4.0 wt. % U-235
Maximum Pellet Enrichment:	4.4 wt. % U-235
Minimum Initial Bundle Average Enrichment:	2.0 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 2: Maximum Burnup:	35,000 MWd/MTU
Minimum Cooling Time:	8-years
Maximum Initial Lattice Average Enrichment :	4.0 wt. % U-235
Maximum Pellet Enrichment:	4.4 wt. % U-235
Minimum Initial Bundle Average Enrichment:	2.65 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 3: Maximum Burnup:	37,200 MWd/MTU
Minimum Cooling Time:	6.5-years
Maximum Initial Lattice Average Enrichment:	4.0 wt. % U-235
Maximum Pellet Enrichment:	4.4 wt. % U-235
Minimum Initial Bundle Average Enrichment:	3.38 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly
Group 4: Maximum Burnup:	40,000 MWd/MTU
Minimum Cooling Time:	10-years
Maximum Initial Lattice Average Enrichment:	4.0 wt. % U-235
Maximum Pellet Enrichment:	4.4 wt. % U-235
Minimum Initial Bundle Average Enrichment:	3.4 wt. % U-235
Maximum Initial Uranium Content:	198 kg/assembly
Maximum Decay Heat:	300 W/assembly

[2] Fuel assemblies fully complying with any of the following groups of parameters are suitable for storage in the NUHOMS®-61BT DSC.

Table K.2-3
BWR Fuel Assembly Design Characteristics[(1) (3)]

Transnuclear, ID	7 x 7-49/0	8 x 8-63/1	8 x 8-62/2	8 x 8 - 60/4	8 x 8-60/1	9 x 9-74/2	10x10-92/2
GE Designations	GE2 GE3	GE4	GE-5 GE-Pres GE-Barrier GE8 Type I	GE8 Type II	GE9 GE10	GE11 GE13	GE12
Max Length (in)	176.2	176.2	176.2	176.2	176.2	176.2	176.2
Max Width (in) (excluding channels)	5.44	5.44	5.44	5.44	5.44	5.44	5.44
Channel Internal Width (in)	5.278	5.278	5.278	5.278	5.278	5.278	5.278
Maximum MTU/assembly[(2)]	0.1977	0.1880	0.1856	0.1825	0.1834	0.1766	0.1867

(1) Any fuel channel thickness from 0.065 to 0.120 inch is acceptable on any of the fuel designs.
(2) The maximum MTU/assembly is calculated based on the theoretical density. The calculated value is higher than the actual.
(3) Maximum fuel assembly weight with channel is 705 lb.

Table K.2-4
BWR Fuel Assembly Poison Material Design Requirements

NUHOMS®-61BT DSC Type	Maximum Lattice Average Enrichment[1] (wt. % U-235)	Minimum B-10 Content in Poison Plates (g/cm2)	% Credit of B10 used in Critically Calculation	Poison Material Coupon Testing
A	3.7	0.018	90	Neutron Transmission plus Radiography
B	4.1	0.023	90	Neutron Transmission plus Radiography
C	4.4	0.029	90	Neutron Transmission plus Radiography

[1] Maximum pin enrichment is 5% U235 in all cases.

Table K.2-5
Summary of Canister Load Combinations

Load Case	Horizontal DW		Vertical DW		Internal Pressure[9]	External Pressure	Thermal Condition	Liting Loads	Other Loads	Service Level	Enveloped By
	61BT DSC	Fuel	61BT DSC	Fuel							
Non-Operational Load Cases											
NO-1 Fab. Leak Testing	--	--	--	--	--	14.7 psi (101kpa)	70°F (21°C)	--	155 kip axial (689KN)	Test	
NO-2 Fab. Leak Testing	--	--	--	--	12 psi (83kpa)	--			155 kip axial	Test	
NO-3 DSC Uprighting	x	--	--	--	--	--	70°F	x	--	A	
NO-4 DSC Vertical Lift	--	--	x	--	--	--	70°F	x	--	A	
Fuel Loading Load Cases											
FL-1 DSC/Cask Filling	--	--	Cask	--	--	Hydrostatic	100°F Cask (38°C)	x	x	A	DD-2
FL-2 DSC/Cask Filling	--	--	Cask	--	Hydrostatic	Hydrostatic	100°F Cask	x	x	A	DD-2
FL-3 DSC/Cask Xfer	--	--	Cask	--	Hydrostatic	Hydrostatic	100°F Cask	--	--	A	
FL-4 Fuel Loading	--	--	Cask	x	Hydrostatic	Hydrostatic	100°F Cask	--	--	A	
FL-5 Xfer to Decon	--	--	Cask	x	Hydrostatic	Hydrostatic	100°F Cask	--	--	A	
FL-6 Inner Cover plate Welding	--	--	Cask	x	Hydrostatic	Hydrostatic	100°F Cask	--	--	A	
FL-7 Fuel Deck Seismic Loading	--	--	Cask	x	Hydrostatic	Hydrostatic	100°F Cask	--	Note 10	C	
Draining/Drying Load Cases											
DD-1 DSC Blowdown	--	--	Cask	x	Hydrostatic + 20 psi (138kpa)	Hydrostatic	100°F Cask	--	--	A	DD-2
DD-2 Vacuum Drying	--	--	Cask	x	0 psia	Hydrostatic + 14 psi (97kpa)	100°F Cask	--	--	A	
DD-3 Helium Backfill	--	--	Cask	x	12 psi (83kpa)	Hydrostatic	100°F Cask	--	--	A	
DD-4 Final Helium Backfill	--	--	Cask	x	3.5 psi (24kpa)	Hydrostatic	100°F Cask	--	--	A	DD-3
DD-5 Outer Cover Plate Weld	--	--	Cask	x	3.5 psi (24kpa)	Hydrostatic	100°F Cask	--	--	A	DD-3
Transfer Trailer Loading											
TL-1 Vertical Xfer to Trailer	--	--	Cask	x	10 psi (69kpa)	--	0°F Cask (-17°C)	--	--	A	
TL-2 Vertical Xfer to Trailer	--	--	Cask	x	10 psi	--	100°F Cask	--	--	A	
TL-3 Laydown	Cask	X	--	--	10 psi	--	0°F Cask	--	--	A	TR-1-TR-4
TL-4 Laydown	Cask	X	--	--	10 psi	--	100°F Cask	--	--	A	TR-5-TR-6

Table K.2-5
Summary of Canister Load Combinations
(continued)

Load Case	Horizontal DW		Vertical DW		Internal Pressure(9)	External Pressure	Thermal Condition	Handling Loads	Other Loads	Service Level	Enveloped By
	61BT DSC	Fuel	61BT DSC	Fuel							
Transfer To/From ISFSI											
TR-1 Axial Load - Cold	Cask	X	--	--	10.0 psi (70kpa)	--	0°F (-17°C)	1g Axial	--	A	
TR-2 Transverse Load - Cold	Cask	X	--	--	10.0 psi	--	0°F	1g Transverse	--	A	
TR-3 Vertical Load - Cold	Cask	X	--	--	10.0 psi	--	0°F	1g Vertical	--	A	
TR-4 Oblique Load - Cold	Cask	X	--	--	10.0 psi	--	0°F	½ g Axial + ½ g Trans + ½ g Vert.	--	A	
TR-5 Axial Load - Hot	Cask	X	--	--	10.0 psi	--	100°F	1g Axial	--	A	
TR-6 Transverse Load - Hot	Cask	X	--	--	10.0 psi	--	100°F	1g Trans.	--	A	
TR-7 Vertical Load - Hot	Cask	X	--	--	10.0 psi	--	100°F	1g Vertical	--	A	
TR-8 Oblique Load - Hot	Cask	X	--	--	10.0 psi	--	100°F	½ g Axial + ½ g Trans + ½ g Vert.	--	A	
TR-9 25g Corner Drop	Note 1		--	--	20 psi	--	100°F(2)		25g Corner Drop	D	
TR-10 75g Side Drop	Note 1		--	--	20 psi	--	100°F(2)		75g Side Drop	D	
TR-11 Top or Bottom End Drops			Note 12		20 psi	--	100°F(2)		75g End Drop	D	

Table K.2-5
Summary of Canister Load Combinations
(continued)

HSM LOADING	Horizontal DW 61BT DSC	Horizontal DW Fuel	Vertical DW 61BT DSC	Vertical DW Fuel	Internal Pressure(9)	External Pressure(9)	Thermal Condition	Handling Loads	Other Loads	Service Level	Enveloped By:
LD-1 Normal Loading - Cold	Cask	X	--	--	10.0 psi (69kpa)	--	0°F Cask (-17°C)	+80 Kip (356KN)	--	A	LD-4
LD-2 Normal Loading – Hot	Cask	X	--	--	10.0 psi	--	100° F Cask	+80 Kip	--	A	LD-5
LD-3	Cask	X	--	--	10.0 psi	--	125° F w/shade(5)	+80 Kip	--	A	LD-2
LD-4 Off-Normal Loading – Cold	Cask	X	--	--	20.0 psi	--	0° F Cask	+80 Kip	FF	B	
LD-5 Off-Normal Loading - Hot	Cask	X	--	--	20.0 psi	--	100° F Cask	+80 Kip	FF	B	
LD-6	Cask	X	--	--	20.0 psi	--	125° F w/shade(5)	+80 Kip	-- FF	B	LD-5
LD-7 Accident Loading	Cask	X	--	--	20.0 psi	--	125° F w/shade(5)	+80 Kip	-- FF	C/D	
HSM STORAGE											
HSM-1 Off-Normal	HSM	X	--	--	10.0 psi	--	-40° F HSM	--	--	B	
HSM-2 Normal Storage	HSM	X	--	--	10.0 psi	--	0° F HSM	--	--	A	HSM-1
HSM-3 Off-Normal	HSM	X	--	--	10.0 psi	--	125° F HSM	--	--	B	
HSM-4 Off-Normal Temp. + Damaged Fuel	HSM	X	--	--	20.0 psi	--	125° F HSM	--	FF	C	
HSM-5 Blocked Vent Storage	HSM	X	--	--	65.0(8) psi	--	125° F HSM/BV(4)	--	--	D	
HSM-6 B.V. + Damaged Fuel Storage	HSM	X	--	--	65.0(8) psi	--	125° F HSM/BV(4)	--	FF	D	
HSM-7 Earthquake Loading – Cold	HSM	X	--	--	10.0 psi	--	0° F HSM	--	FF+EQ	C	
HSM-8 Earthquake Loading – Hot	HSM	X	--	--	10.0 psi	--	100°F HSM	--	FF+EQ	C	
HSM-9 Flood Load (50' H_2O) – Cold	HSM	X	--	--	0 psi	22 psi	0° F HSM	--	Flood(3)	C	
HSM-10 Flood Load (50' H_2O) - Hot	HSM	X	--	--	0 psi	22 psi	100°F HSM	--	Flood(3)	C	

HSM UNLOADING	Horizontal DW 61BT DSC	Horizontal DW Fuel	Vertical DW 61BT DSC	Vertical DW Fuel	Internal Pressure(9)	External Pressure(9)	Thermal Condition	Handling Loads	Other Loads	Service Level	Enveloped By:
UL-1 Normal Loading - Cold	HSM	X	--	--	10.0 psi	--	0°F HSM	+60 Kip	--	A	UL-4
UL-2 Normal Loading – Hot	HSM	X	--	--	10.0 psi	--	100° F HSM	+60 Kip	--	A	UL-5
UL-3	HSM	X	--	--	10.0 psi	--	125° F w/shade	+60 Kip	--	A	UL-2
UL-4 Off-Normal Loading – Cold	HSM	X	--	--	20.0 psi	--	0° F HSM	+60 Kip	FF	B	
UL-5 Off-Normal Loading - Hot	HSM	X	--	--	20.0 psi	--	100° F HSM	+60 Kip	FF	B	
UL-6	HSM	X	--	--	20.0psi	--	125° F w/shade	+60 Kip	FF	B	UL-5
UL-7 Off. Norm. Unloading-FF/Hot(6,16)	HSM	X	--	--	20.0 psi	--	100° F HSM	+80 Kip	FF	C	
UL-8 Accident Unloading – FF/Hot(7,16)	HSM	X	--	--	65.0(7,8) psi	--	100° F HSM	+80 Kip	FF	D	

HSM UNLOADING / REFLOOD	Horizontal DW 61BT DSC	Horizontal DW Fuel	Vertical DW 61BT DSC	Vertical DW Fuel	Internal Pressure(9)	External Pressure(9)	Thermal Condition	Handling Loads	Other Loads	Service Level	Enveloped By:
RF-1 DSC Reflood	--	--	Cask	X	20.0 psi (max)	Hydrostatic	100° F Cask	--	--	D	HSM-5&6

Table K.2-5
Summary of Canister Load Combinations
(continued)

1. 75g drop acceleration includes gravity effects. Therefore, it is not necessary to add an additional 1.0g load.
2. For Level D events, only maximum temperature case is considered. (Thermal stresses are not limited for level D events and maximum temperatures give minimum allowables).
3. Flood load is an external pressure equivalent to 50 feet (164m) of water.
4. BV = HSM Vents are blocked.
5. At temperature over 100° F (38°C) a sunshade is required over the Transfer Cask. Temperatures for these cases are enveloped by the 100° F (without sunshade) case.
6. As described in Section 4.1.2, this pressure assumes release of the fuel cover gas and 30% of the fission gas. Since unloading requires the HSM door to be removed, the pressure and temperatures are based on the normal (unblocked vent) condition. Pressure is applied to the inner pressure boundary.
7. As described in Section 4.1.2, this pressure assumes release of the fuel cover gas and 30% of the fission gas. Although unloading requires the HSM door to be removed, the pressure and temperatures are based on the blocked vent condition. Pressure is applied to the outer pressure boundary.
8. This pressure is applied to the outer pressure boundary.
9. Unless noted otherwise, pressure is applied to the inner pressure boundary.
10. Fuel deck seismic loads are assumed enveloped by handling loads.
11. Load Cases UL-7 and UL-8 envelop loading cases where the insertion loading of 80 kips (356KN) is considered with an accident pressure (the insertion force is opposed by internal pressure).
12. The 75g top end drop and bottom end drop are not credible events, therefore these drop analyses are not required.

Table K.2-6
Canister Allowable Stress

STRESS CATEGORY	STRUCTURE ALLOWABLE STRESSES[3]	
	Normal Conditions	Accident Conditions
Primary Membrane General P_m	S_m	Lesser of $2.4S_m$ or $0.7\ S_u$ [1]
Local P_L	$1.5\ S_m$	Lesser of $3.6\ S_m$ or $1.0\ S_u$ [1]
Primary Membrane + Bending (P_m or P_L) + P_b	$1.5\ S_m$	Lesser of $3.6\ S_m$ or $1.0\ S_u$ [1]
Range of Primary + Secondary (P_m or P_L) + P_b + Q	$3.0\ S_m$	$2 \times S_a$ for 10 Cycles (Reg. Guide 7.6)
Bearing Stress	S_y	S_y for Seal Surface S_u Elsewhere
Buckling[2]	Factor of Safety = 2.0 Code Case N-284	Factor of Safety = 1.34 Code Case N-284
Pure Shear Stress	$0.6\ S_m$	$0.42\ S_u$
Fatigue	Usage Factor ≤ 1	Not Applicable

Notes:

1. When evaluating the results from the nonlinear elastic plastic analysis for the accident conditions, the general primary membrane stress intensity, P_m, shall not exceed $0.7\ S_u$ and the maximum primary stress intensity at any location (P_L or $P_L + P_b$) shall not exceed $0.9\ S_u$. These limits are in accordance with Appendix F of Section III of the Code.
2. Other acceptable criteria are also provided in Section III of the ASME Code and NUREG/CR-6322.
3. Reference to Section III, Subsection NB, Para. NB-3223 and NB-3224 for Level B and Level C stress limits.

Table K.2-7
Basket Stress Limits

STRESS CATEGORY	ALLOWABLE STRESSES[6]	
	Normal Conditions[1]	Accident Conditions[2]
Primary Membrane General P_m Local P_L	S_m 1.5 S_m	Lesser of 2.4 S_m or 0.7 S_u [3] Lesser of 3.6 S_m or 1.0 S_u [3]
Primary Membrane + Bending (P_m or P_L) + P_b	1.5 S_m	Lesser of 3.6 S_m or 1.0 S_u [3]
Range of Primary + Secondary (P_m or P_L) + P_b + Q	3.0 S_m	2S_a for 10 cycles [4]
Bearing Stress	S_y	Not applicable
Average. Primary Shear Stress	0.6 S_m	0.42 S_u
Buckling[7]	Compressive Stress limit per NF-3322.1(c)	100% of the plastic analysis collapse load or test collapse load[5]
Fatigue	Cumulative fatigue usage factor ≤ 1	Not applicable

Notes:
1. ASME Code, Section III, Appendix NG, service level A
2. ASME Code, Section III, Appendix F, service level D
3. When evaluating the results from the nonlinear elastic-plastic analysis for the accident conditions, the general primary membrane stress intensity, P_m, shall not exceed 0.7S_u and the maximum primary stress intensity at any location (P_L or $P_L + P_b$) shall not exceed 0.9 S_u.
4. ASME Code Section III, Appendix 1 and Reg. Guide 7.6.
5. ASME Code, Section III, Appendix F, Para. F-1341.3
6. Reference to Section III, Subsection NG, Para. NG-3223 and NG-3224 for Level B and Level C Stress Limits.
7. Other acceptable criteria are also provided in Section III of the ASME Code and NUREG/CR-6322.

Table K.2-8
Classification of NUHOMS®-OS197-1 DSC Components

IMPORTANT TO SAFETY	NOT IMPORTANT TO SAFETY
Canister Assembly	Siphon tube
Canister shell	Quick connect coupling
Bottom shield plug	Male connector
Inner bottom cover	Alignment key
Outer bottom cover	Canister lifting lug
Grapple ring and support	
Top shield plug	
Inner top cover plate	
Outer top cover plate	
Siphon/vent port cover plate	
Siphon vent block	
Support ring segment	
Vent port plug	
Storage Basket Assembly	
Fuel compartment	
Fuel compartment wrap	
Poison plate	
Basket plate	
Weld Stud, washer, hex nut	
Basket plate insert	
Basket rail	
Basket holddown plate	
Spacer pad	
Alignment leg	

Table K.2-9
Additional Design Criteria for NUHOMS®-61BT DSC

IMPORTANT TO SAFETY	NOT IMPORTANT TO SAFETY
The gross weight of the NUHOMS®-61BT DSC:	88.5 kips
NUHOMS®-61BT DSC Type:	A, B or C
Payload Capacity:	61 intact BWR assemblies 61 BWR assemblies (up to 16 damaged and remainder intact) (acceptable assemblies listed in Table K.2-3)
Spent Fuel Characteristics:	See Tables K.2-1, K.2-2, K.2-4

K.3 Structural Evaluation

K.3.1 Structural Design

K.3.1.1 Discussion

This section describes the structural evaluation of the NUHOMS®-61BT system. The NUHOMS®-61BT system consists of the NUHOMS® HSM, the OS-197 transfer cask, the 61BT DSC and the 61BT basket assembly. No changes have been made to the HSM or the OS-197 transfer cask to accommodate the 61BT DSC or basket. Where the new components have an effect on the structural evaluations presented in the CSAR, the changes are included in this section. Sections that do not effect the evaluations presented in the CSAR are identified as "No Change". In addition, a complete evaluation of the 61BT DSC and basket are provided in this section.

The 61BT DSC is shown on drawings NUH-61B-1060, NUH-61B-1061 and NUH-61B-1062 in Section K1.5. The 61BT DSC is the same as the 52B DSC with the following exceptions:

- The DSC shell thickness has been reduced to 0.5 inch thick from 0.625 inch thick to allow additional room inside the DSC for the additional fuel assemblies.
- The thickness of the top shield plug has been reduced from 8.0 inches to 7.0 inches.
- The thickness of the bottom shield plug has been reduced from 5.75 inches to 5.00 inches.
- The bottom closure weld has been modified to be compliant with the ASME Code Subsection NB.
- A test port has been added to the top cover plate to allow testing of the inner cover plate welds to a leak tight criteria.

The NUHOMS®-61BT basket is a welded assembly of stainless steel boxes and designed to accommodate 61 BWR fuel assemblies. The basket structure consists of an assembly of stainless steel tubes (fuel compartments) separated by poison plates and surrounded by larger stainless steel boxes and support rails. The basket contains 61 compartments for proper spacing and support of the fuel assemblies. The 61BT basket assembly is shown on drawings NUH-61B-1063, NUH-61B-1064, and NUH-61B–1065.

The basket structure is open at each end and therefore, longitudinal fuel assembly loads are applied directly to the DSC/cask body and not on the fuel basket structure. The fuel assemblies are laterally supported in the stainless steel structural boxes. The basket is laterally supported by the rails and the DSC inner shell.

The basket is keyed to the DSC at 180° and therefore its orientation with respect to the DSC always remains fixed. Under normal transfer conditions, DSC rests on two 3" wide transfer support rails, attached to inside of the transfer cask at 161.5° and 198.5°.

The basket assembly includes:

- Four (4) 2 by 2 large boxes (four compartment assembly), each box consists of 4 stainless steel fuel compartments (0.12 in. thick.) separated by poison plates (0.31 in. thick.) and wrapped in a 0.105 in. thick stainless plate.

- Five (5) 3 by 3 large boxes (nine compartment assembly), each box consists of 9 stainless steel fuel compartments (0.135 in. thick.) separated by poison plates (0.31 in. thick.) and wrapped in a 0.105 in. thick. stainless plate.

- Eight (8) type 1 stainless steel rails, the rails are fabricated from 0.19/0.25 in. thick, SA-240, type 304 stainless steel.

- Four (4) type 2 stainless steel rails, the rails are also fabricated from 0.19/0.25 in. thick, SA-240, type 304 stainless steel.

The poison plates provide the heat conduction path from the fuel assemblies to the DSC cavity wall, and also provide the necessary criticality control. The nominal open dimension of each fuel compartment cell is 6.0 in. x 6.0 in. which provides clearance around the fuel assemblies. The overall basket length including holddown ring (178.5 in.) is less than the DSC cavity length to allow for thermal expansion and tolerances and access to the top of the fuel assemblies.

Stainless steel rails are oriented parallel to the axis of the DSC and attached to the periphery of the basket to establish and maintain basket orientation and to support the basket.

Stainless steel plate inserts (0.31 in. thick × 3 in. wide × 3.5 in. long) are placed between the stainless steel tubes and between the outer wrappers at the top and bottom of the basket assembly. These plate inserts are fillet welded to the stainless steel tubes and wrappers to prevent the poison plates from sliding in the axial direction.

The basket holddown ring is set between the top of the basket assembly and inside surface of the DSC top shield plug assembly. The holddown ring is used to prevent the basket assembly from sliding freely in the axial direction during the handling/transfer and operation/storage loading conditions.

End caps are installed at the bottom and top of basket cells which contain damaged fuel. These end caps are shown on Dwg. NUH-61B-1066.

K.3.1.2 Design Criteria

Design criteria for this section is provided in Section K.2.5.

K.3.1.2.1 DSC Confinement Boundary

The primary confinement boundary consists of the DSC shell, the inner top cover plate, the inner bottom cover plate, the siphon vent block, and the siphon/vent port cover plate. The basis for the allowable stresses for the confinement boundary is ASME Code Section III, Division I, Subsection NB Article NB-3200 [3.1] for normal condition loads (Level A), off normal condition loads (Level B and C) and Appendix F for accident condition loads (Level D). See Section K.2.2 for additional design criteria.

K.3.1.2.2 DSC Basket

The basket is designed to meet the heat transfer, nuclear criticality, and the structural requirements. The basket structure must provide sufficient rigidity to maintain a subcritical configuration under the applied loads. The 304 stainless steel members in the NUHOMS®-61BT basket are the primary structural components. The neutron poison plates are the primary heat conductors, and provide the necessary criticality control.

The stress analyses of the basket for normal and accident conditions do not take credit for the poison plates except for through-thickness-compression. However, the weight of the poison plates is included in the stress evaluations.

The basis for the allowable stresses for the 304 stainless steel basket assembly is Section III, Division I, Subsection NG of the ASME Code [3.1]. The hypothetical impact accidents are evaluated as short duration, Level D conditions. The stress criteria are taken from Section III, Appendix F of the ASME Code [3.1]. See Section K2.2 for additional design criteria. The basket stress limits are provided for information in Table K.3.1-1.

The basket holddown ring is set between the top of the basket assembly and inside surface of the DSC top shield plug. The holddown ring is used to prevent the basket assembly from sliding freely in the axial direction during the handling/transfer and operation/storage loading conditions. The basket holddown ring is designed, fabricated and inspected in accordance with the ASME Code Subsection NF [3.1], to the maximum practical extent.

Table K.3.1-1
Numerical Values of Primary Stress Intensity Limits

(304 SS at 650°F)

Stress Category	Allowable Stresses		
	Normal Conditions (Level A)	Accident Conditions (Level D)	
	Elastic Analysis (ksi)	Elastic/Plastic Analysis (ksi)	Elastic Analysis (ksi)
Primary Membrane Stress Intensity (P_m)	16.2	44.38	38.88
Local Membrane Stress Intensity (P_L)	24.3	57.06	58.32
Primary Membrane + Bending Stress Intensity (P_m+ P_b)	24.3	57.06	58.32
Primary Membrane + Secondary Stress Intensity Range (P_m+ P_b+ Q)	48.6	N/A	N/A
Shear	9.72	26.63	26.63
Bearing Stress (S_b)	26.85	N/A	N/A

K.3.2 Weights and Centers of Gravity

Table K.3.2-1 shows the weights of the various components of the NUHOMS®-61BT System including basket, DSC, standard HSM and OS197 transfer cask. The dead weights of the components are determined based on the nominal dimensions.

Table K.3.2-1
Summary of the NUHOMS®-61BT System Component Weights

Component Description	Calculated Weight (kips)
DSC Shell Assembly	13.52
DSC Top Shield Plug Assembly	8.95
DSC Internal Basket Assembly	22.92
Total Empty Weight	**45.39**
61 BWR Spent Fuel Assemblies	≤ 43.0
Total Loaded DSC Weight (Dry)	**88.39**
Water in Loaded DSC	13.4
Total Loaded DSC Weight (Wet)	**101.79**
Transfer Cask Empty Weight	111.25
Total Loaded Transfer Cask Weight	**199.64**
HSM Single Module Weight (Empty)	**224.0**
HSM Single Module Weight (Loaded)	**312.4**

K.3.3 Mechanical Properties of Materials

K.3.3.1 Material Properties

The mechanical properties of structural materials used in the 61BT DSC and basket are in accordance with ASME Code Section II, Part D [3.2]. A value of 2.78 x 10^{-6} used for the thermal coefficient of expansion for zircaloy is taken from reference [3.3] at a temperature of 850°F.

K.3.3.2 Materials Durability

The materials used in the fabrication of the NUHOMS®-61BT System are shown in Table K.3.6-3. Essentially all of the materials meet the appropriate requirements of the ASME Code, ACI Code and appropriate ASTM Standards. The durability of the shell assembly and basket assembly stainless steel components is well beyond the design life of the applicable components. The small amount of aluminum material used in the basket meets ASME Code standards and is relied upon for its thermal conductivity properties only. The poison material selected for criticality control of the NUHOMS®-61BT System has been tested and is currently in use for similar applications. Additionally, the NUHOMS®-61BT basket assembly resides in an inert helium gas environment for the majority of the design life. The specifications controlling the mix of the concrete, specified minimum concrete strength requirements, and fabrication controls ensure durability of the concrete for this application. The materials used in the NUHOMS®-61BT System will maintain the required properties for the design life of the system.

K.3.4 General Standards for Casks

K.3.4.1 Chemical and Galvanic Reactions

The materials of the 61BT DSC and basket have been reviewed to determine whether chemical, galvanic or other reactions among the materials, contents and environment might occur during any phase of loading, unloading, handling or storage. This review is summarized below:

The 61BT DSC is exposed to the following environments:

- During loading and unloading, the DSC is placed in pool water, inside of the OS-197 transfer cask. The annulus between the cask and DSC is filled with demineralized water and an inflatable seal is used to cover the annulus between the DSC and cask. The exterior of the DSC will not be exposed to pool water.

- The space between the top of the DSC and inside of the transfer cask is sealed to prevent contamination. For BWR plants the pool water is deionized. This affects the interior surfaces of the DSC, lid and the basket. The transfer cask and DSC are only kept in the spent fuel pool for a short period of time, typically about 6 hours to load or unload fuel, and 2 hours to lift the loaded transfer cask/DSC out of the spent fuel pool.

- During storage, the interior of the DSC is exposed to an inert helium environment. The helium environment does not support the occurrence of chemical or galvanic reactions because both moisture and oxygen must be present for a reaction to occur. The DSC is thoroughly dried before storage by a vacuum drying process. It is then backfilled with helium, thus stopping corrosion. Since the DSC is vacuum dried, galvanic corrosion is also precluded as there is no water present at the point of contact between dissimilar metals.

- During storage, the exterior of the DSC is protected by the concrete NUHOMS® HSM. The HSM is vented, so the exterior of the DSC is exposed to the atmosphere. The DSC is fabricated from austenitic stainless steel and is generally resistant to corrosion.

The NUHOMS®-61BT DSC materials are shown in the Parts List on Drawing NUH-61B-1065, provided in Section K.1.5. The DSC shell material is SA-240 Type 304 Stainless Steel. The top and bottom shield plug material is A-36 carbon steel and the top shield plug is coated with an electroless nickel coating.

The basket holddown structure is SA-240, Type 304 stainless steel. The basket is constructed from enriched boron aluminum or boron carbide/aluminum metal matrix composite (neutron poison) plates sandwiched between SA-240 Type 304 stainless steel tubes. The neutron poison is not welded or bolted to the stainless steel, but is held in place by the geometry of the boxes and stainless steel plates. On the periphery of the basket, some of the poison plates are replaced with SA-240 stainless steel plates. The basket rails are constructed from SA-240 type 304 stainless steel plate.

Potential sources of chemical or galvanic reactions are the interaction between the aluminum, aluminum-based neutron poison and stainless steel within the basket itself and the pool water, and the interaction of the stainless steel top and bottom plates with the top and bottom shield plugs.

Typical water chemistry in a BWR Spent Fuel pool is as follows:

pH	5.6 - 7.1
Chloride	1 - 10 ppb
Conductivity	0.7 - 1.8 μmho
Silica	2.5 - 2.7 ppm
Pool Temperature	70 - 115°F

A. Behavior of Aluminum in Deionized Water

Aluminum is used for many applications in spent fuel pools. In order to understand the corrosion resistance of aluminum within the normal operating conditions of spent fuel storage pools, a discussion of each of the types of corrosion is addressed separately. None of these corrosion mechanisms are expected to occur in the short time period that the DSC is submerged in the spent fuel pool.

General Corrosion

General corrosion is a uniform attack of the metal over the entire surfaces exposed to the corrosive media. The severity of general corrosion of aluminum depends upon the chemical nature and temperature of the electrolyte and can range from superficial etching and staining to dissolution of the metal. Figure K.3.4-1 shows a potential -pH diagram for aluminum in high purity water at 77°F. The potential for aluminum coupled with stainless steel and the limits of pH for BWR pools are shown in the diagram to be well within the passivation domain. The passivated surface of aluminum (hydrated oxide of aluminum) affords protection against corrosion in the domain shown because the coating is insoluble, non-porous and adherent to the surface of the aluminum. The protective surface formed on the aluminum is known to be stable up to 275°F and in a pH range of 4.5 to 8.5 [3.4].

Galvanic Corrosion

Galvanic corrosion is a type of corrosion which could cause degradation of dissimilar metals exposed to a corrosive environment for a long period of time.

Galvanic corrosion is associated with the current of a galvanic cell consisting of two dissimilar conductors in an electrolyte. The two dissimilar conductors of interest in this discussion are aluminum and stainless steel in deionized water. There is little galvanic corrosion in deionized water since the water conductivity is very low. There is also less galvanic current flow between the aluminum-stainless steel couple than the potential difference on stainless steel which is known as polarization. It is because of this polarization characteristic that stainless steel is compatible with aluminum in all but severe marine, or high chloride, environmental conditions [3.5].

Pitting Corrosion

Pitting corrosion is the forming of small sharp cavities in a metal surface. The first step in the development of corrosion pits is a local destruction of the protective oxide film. Pitting will not occur on commercially pure aluminum when the water is kept sufficiently pure, even when the aluminum is in electrical contact with stainless steel. Pitting and other forms of localized corrosion occur under conditions like those that cause stress corrosion, and are subject to an induction time which is similarly affected by temperature and the concentration of oxygen and chlorides. As with stress corrosion, at the low temperatures and low chloride concentrations of a spent fuel pool, the induction time for initiation of localized corrosion will be greater than the time that the DSC internal components are exposed to the aqueous environment.

Crevice Corrosion

Crevice corrosion is the corrosion of a metal that is caused by the concentration of dissolved salts, metal ions, oxygen or other gases in crevices or pockets remote from the principal fluid stream, with a resultant build-up of differential galvanic cells that ultimately cause pitting. Crevice corrosion could occur in the basket plates, around the stainless steel welds. However, due to the short time in the spent fuel pool, this type of corrosion is not expected to be significant.

Intergranular Corrosion

Intergranular corrosion is corrosion occurring preferentially at grain boundaries or closely adjacent regions without appreciable attack of the grains or crystals of the metal itself. Intergranular corrosion does not occur with commercially pure aluminum and other common work hardened aluminum alloys.

Stress Corrosion

Stress corrosion is failure of the metal by cracking under the combined action of corrosion and high stresses approaching the yield stress of the metal. During normal operations, the stresses on the basket plates are very small, well below the yield stress of the basket materials. Therefore, stress corrosion in the basket and DSC components will be negligible.

B. Behavior of Austenitic Stainless Steel in Deionized Water

The fuel compartments and the structural rails and boxes which support the fuel compartments are made from Type 304 stainless steel. Stainless steel does not exhibit general corrosion when immersed in deionized water. Galvanic attack can occur between the aluminum in contact with the stainless steel in the water. However, the attack is mitigated by the passivity of the aluminum and the stainless steel in the short time the pool water is in the DSC. Also the low conductivity of the pool water tends to minimize galvanic reactions.

Stress corrosion cracking in the Type 304 stainless steel welds of the basket is also not expected to occur, since the baskets are not highly stressed during normal operations. There may be some residual fabrication stresses as a result of welding of the stainless steel boxes to the basket plate inserts. Of the corrosive agents that could initiate stress corrosion cracking in the 304 stainless steel basket welds, only the combination of chloride ions with dissolved oxygen occurs in spent fuel pool water. Although stress corrosion cracking can take place at very low chloride concentrations and temperatures such as those in spent fuel pools (less than 10 ppb and 160°F, respectively), the effect of low chloride concentration and low temperature is to greatly increase the induction time, that is, the period during which the corrodent is breaking down the passive oxide film on the stainless steel surface. Below 60°C (140°F), stress corrosion cracking of austenitic stainless steel does not occur at all. At 100 °C (212 °F), chloride concentration on the order of 15% is required to initiate stress corrosion cracking [3.6]. At 288 °C (550 °F), with tensile stress at 100% of yield in BWR water containing 100 ppm O_2, time to crack is about 40 days in sensitized 304 stainless steel [3.7]. Thus, the combination of low chlorides, low temperature and short time of exposure to the corrosive environment eliminates the possibility of stress corrosion cracking in the basket and DSC welds.

The chloride content of all expendable materials which come in contact with the basket materials are restricted and water used for cleaning the baskets is restricted to 1.0 ppm chloride.

C. Behavior of Aluminum Based Neutron Poison in Deionized Water

The aluminum component of the borated aluminum is a ductile metal having a high resistance to corrosion. Its corrosion resistance is provided by the buildup of a protective oxide film on the metal surface when exposed to a corrosive environment. As stated above for aluminum, once a stable film develops, the corrosion process is arrested at the surface of the metal. The film remains stable over a pH range of 4.5 to 8.5.

Tests were performed by Eagle Picher [3.8] which concluded that borated aluminum exhibits a strong corrosion resistance at room temperature in deionized water. Satisfactory long-term usage in these environments is expected. At high temperature, the borated aluminum still exhibits high corrosion resistance in the pure water environment.

From tests on pure aluminum, it was found that borated aluminum was more resistant to uniform corrosion attack than pure aluminum [3.8].

The alternate neutron poison material is a boron carbide / aluminum composite. The billet is produced by blending of aluminum and boron carbide powders, cold isostatic compacting, and vacuum sintering. The plates are formed from the billet by rolling or extrusion. The result is a matrix of full-density aluminum with a fine dispersion of boron carbide particles throughout. The corrosion behavior is similar to that of the base aluminum alloy.

There are no chemical, galvanic or other reactions that could reduce the areal density of boron in the neutron poison plates with either of the poison plate materials.

D. Electroless Nickel Plated Carbon Steel

The carbon steel top shield plug of the DSC is plated with electroless nickel. This coating is identical to the coating used on the 52B DSC. It has been evaluated for potential galvanic reactions in Transnuclear West's response to NRC Bulletin 96-04 [3.9]. In BWR pools, the reported corrosion rates are insignificant and are expected to result in a negligible rate of reaction for the NUHOMS® BWR systems.

Lubricants and Cleaning Agents

Lubricants and cleaning agents used on the NUHOMS®-61BT DSC are limited to those with chlorine contents of less than 1 ppm chloride. Never-seez or Neolube (or equivalent) is used to coat the threads and bolt shoulders of the closure bolts. The lubricant should be selected for compatibility with the spent fuel pool water and the DSC materials, and for its ability to maintain lubricity under long term storage conditions.

The DSC is cleaned in accordance with approved procedures to remove cleaning residues prior to shipment to the storage site. The basket is also cleaned prior to installation in the DSC. The cleaning agents and lubricants have no significant affect on the DSC materials and their safety related functions.

Hydrogen Generation

During the initial passivation state, small amounts of hydrogen gas may be generated in the 61BT DSC. The passivation stage may occur prior to submersion of the transfer cask into the spent fuel pool. Any amounts of hydrogen generated in the DSC will be insignificant and will not result in a flammable gas mixture within the DSC.

The small amount of hydrogen which may be generated during DSC operations does not result in a safety hazard. In order for concentrations of hydrogen in the cask to reach flammability levels, most of the DSC would have to be filled with water for the hydrogen generation to occur, and the lid would have to be in place with both the vent and drain ports closed. This does not occur during DSC loading or unloading operations.

After loading fuel into the NUHOMS®-61BT DSC, the shield plug is placed in the DSC and the transfer cask and DSC are raised to the pool surface. At this time the DSC is completely filled with water.

An estimate of the maximum hydrogen concentration can be made, ignoring the effects of radiolysis, recombination, and solution of hydrogen in water. Testing was conducted by Transnuclear [3.10] to determine the rate of hydrogen generation for aluminum metal matrix composite in intermittent contact with 304 stainless steel. The samples represent the neutron poison plates paired with the basket compartment tubes. The test specimens were submerged in deionized water for 12 hours at 70 °F to represent the period of initial submersion and fuel loading, followed by 12 hours at 150 °F to represent the period after the fuel is loaded, until the water is drained. The hydrogen generated during each period was removed from the water and the test vessel and measured.

The test results were:

	12 hour @ 70 °F		12 hour @ 150 °F	
	$cm^3hr^{-1}dm^{-2}$	$ft^3hr^{-1}ft^{-2}$	$cm^3hr^{-1}dm^{-2}$	$ft^3hr^{-1}ft^{-2}$
aluminum MMC/SS304	0.517	1.696E-4	0.489	1.604E-4

The total surface area of the aluminum/stainless steel interface at the neutron absorber/compartment wall interface is 1462 ft^2. This surface area, combined with the test data at 150 °F above result in a hydrogen generation rate of

$$(1.6x10^{-4}\ ft^3/ft^2hr)(1462\ ft^2)] \ =0.23\ ft^3/hr$$

in the 61BT DSC. During welding of the top inner plate, the DSC is partially filled with water. The minimum free volume of the DSC is 120 cu. feet (based on 60 inches of space between the top inner plate and the water). The following assumptions are made to arrive at a conservative estimate of hydrogen concentration:

- All generated hydrogen is released instantly to the plenum between the water and the shield plug, that is, no dissolved hydrogen is pumped out with the water, and no released hydrogen escapes through the open vent port, and

- The welding and backfilling process takes 8 hours to complete.

Under these assumptions, the hydrogen concentration in the space between the water and the shield plug is a function of the time water is in the DSC prior to backfilling with helium. The hydrogen concentration is ($0.23\ ft^3\ H_2/hr$)*(8 hr) / (120 ft^3) = 1.5 %. Monitoring of the hydrogen concentration before and during welding operations will be performed to ensure that the hydrogen concentration does not exceed 2.4%. If the concentration exceeds 2.4%, welding operations will be suspended and the DSC will be purged with an inert gas. In an inert atmosphere, hydrogen will not be generated.

Effect of Galvanic Reactions on the Performance of the System

There are no significant reactions that could reduce the overall integrity of the DSC or its contents during storage. The DSC and fuel cladding thermal properties are provided in Section K.4. The emissivity of the fuel compartment is 0.3, which is typical for non-polished stainless steel surfaces. If the stainless steel is oxidized, this value would increase, improving heat transfer. The fuel rod emissivity value used is 0.8, which is a typical value for oxidized Zircaloy. Therefore, the passivation reactions would not reduce the thermal properties of the component cask materials or the fuel cladding.

There are no reactions that would cause binding of the mechanical surfaces or the fuel to basket compartment boxes due to galvanic or chemical reactions.

There is no significant degradation of any safety components caused directly by the effects of the reactions or by the effects of the reactions combined with the effects of long term exposure of the materials to neutron or gamma radiation, high temperatures, or other possible conditions.

K.3.4.2 Positive Closure

Positive closure is provided by the OS 197 transfer cask. No change.

K.3.4.3 Lifting Devices

The trunnions have been evaluated for an OS197 cask weight of at least 240,000/1.15 = 208,696 lbs. The maximum weight of the lifted OS197 cask with the 61BT DSC is 202,219 lbs., which is less than the evaluated weight. Therefore, the trunnions are acceptable for lifting the OS197 with the 61BT DSC.

K.3.4.4 Heat and Cold

K.3.4.4.1 Summary of Pressures and Temperatures

Temperatures and pressures for the 61BT DSC and basket are calculated in Section K.4. Section K.4.4 provides the thermal evaluation of normal conditions. Section K4.5 provides the thermal evaluation for off-normal conditions. Section K4.6 provides the thermal evaluation of accident conditions. Section K4.7 provides the thermal evaluation during vacuum drying operations. Tables K.4-1, K.4-2 and K.4-4 provide the calculated temperatures for the various components during storage, transfer and vacuum drying operations respectively. Table K4-5 provides the maximum pressures during normal, off-normal and accident conditions which are used in the evaluations presented later in this Appendix.

K.3.4.4.2 Differential Thermal Expansion

A. Basket and DSC Temperature Due to Handling/Transfer Thermal Loads

The thermal analyses of the basket for the handling/transfer conditions are described in Section K.4. The thermal analyses are performed to determine the basket/DSC temperatures for -40° F ambient, 100° F ambient and vacuum drying conditions. The temperatures are used to evaluate the effects of axial and radial thermal expansion in the basket/DSC components. The following table summarizes the thermal analysis results from Section K.4.

Summary of Component Temperature due to Handling/Transfer Thermal Loads

Component	Calculated Temperature (°F)			Temperature Selected for Analysis (°F)
	-40 °F	100 °F	Vacuum Drying(2)	
DSC Shell	308	378	369	360
Average Basket Plate(1)	483	544	706	710
ΔT Between DSC Shell and Basket	175	166	337	350
Fuel Cladding	580	638	846	850

Notes: 1. Basket temperature is based on the cross section average temperature.

2. With total decay heat loads in excess of 17.6 kW, administrative controls prevent the vacuum drying process from continuing for more than 96 hours. For conservatism in the determination of thermal expansion during the vacuum drying condition, bounding steady-state temperatures with a maximum total decay heat load of 18.3 kW are used for the evaluation.

From the above table, it is seen that the vacuum drying case is the most critical of all cases since basket temperatures and ΔT between the DSC and basket are the highest. Conservatively selected temperatures are used to verify that adequate clearance exists between different components for free thermal expansion.

B. Basket and DSC Temperature Due to Operation/Storage Thermal Loads

The thermal analysis of the basket for the operation/storage conditions are described in Section K.4. Operation/storage temperatures are calculated with the basket and DSC in the HSM. The thermal analyses are performed to determine the basket temperatures for the operation/storage condition with –40° F ambient,100° F ambient,125° F ambient and a blocked vent conditions. These temperatures are used to evaluate the effects of axial and radial thermal expansion in the basket/DSC components. The following table summarizes the thermal analysis results from Section K.4.

Summary of Component Temperature due to Operation/Storage Thermal Loads

Component	Calculated Temperature (°F)				Temperature Selected For Analysis (°F)
	-40 °F	100 °F	125 °F	Vent Block	
DSC Shell	136	274	298	425[2]	425
Average Basket Plate[1]	350	476	499	693	725
ΔT Between DSC Shell and Basket	214	202	201	268	300
Fuel Cladding	454	569	590	809	810

Notes: 1. Basket temperature is based on the cross section average temperature.
2. Conservatively using temperature at lower – half of the DSC

From the above table, it is seen that the vent block case is the most critical of all cases since temperatures and ΔT between DSC and basket are the highest in this case.

C. Thermal Expansion Calculation

In order to prevent thermal stress, adequate clearance is provided between the poison plates and stainless steel plates, and between the basket outer diameter and DSC cavity inside diameter, for free thermal expansion. To verify that adequate provision exists, the thermal expansion of different components are calculated and tabulated below.

Thermal Expansion of 61BT Components

Fuel Assembly Axial Thermal Expansion						
	F.A. Length at 70°F (in.)*	Max. F.A. Temp (°F)	F.A. Length Hot**	DSC Cavity Length at 70°F (in)	Min. Cavity Temp (°F)	Cavity Length Hot (in)
Handling/Transfer	176.16	850	178.74	179.31	360	179.78
Operation/Storage	176.16	810	178.72	179.31	425	179.90
Basket Diametral Thermal Expansion						
	Basket O.D. at 70°F (in.)	Basket Temp (°F)	Basket O.D. Hot (in)	DSC Cavity I.D. at 70°F (in)	Min. Cavity Temp (°F)	Cavity I.D. Hot (in)
Handling/Transfer	66.0	710	66.41	66.25	360	66.43
Operation/Storage	66.0	725	66.42	66.25	425	66.47
Basket Axial Thermal Expansion (Including Holddown Ring)						
	Basket Length at 70°F (in.)	Basket Temp (°F)	Basket Length Hot (in)	DSC Cavity Length at 70°F (in)	Min. Cavity Temp (°F)	Cavity Length Hot (in)
Handling/Transfer	178.50	710	179.61	179.31	360	179.78
Operation/Storage	178.50	725	179.64	179.31	425	179.90

* The GE 7x7 (longest BWR fuel) is chosen for analysis. Total fuel assembly length at room temperature = 176.16 inches. The length of the zircaloy guide tube is 160.47 inches. The remainder of the fuel assembly length 15.69 inches is stainless steel.

** Includes 1.25 in. for irradiation growth and 0.86 inches for combined height of end cap covers.

As shown in the table above, adequate clearance has been provided for free thermal expansion of the fuel assemblies and the basket.

K.3.4.4.3 Thermal Stress Calculations

The thermal stress calculations for the various system components other than the basket are provided in Sections 3.6 and 3.7 for normal, off-normal and accident conditions. The thermal stress calculations for the 61BT basket is presented below.

A. Basket Thermal Stress Calculation due to Handling/Transfer Thermal Loads

The basket structure consists of an assembly of four (4) 2 by 2 large boxes and five (5) 3 by 3 large boxes and surrounded by eight (8) type 1 rails and four (4) type 2 rails. The support rails are attached to the basket with bolts in slotted holes that cause no resistance to basket thermal expansion. The 2 x 2 boxes, 3 x 3 boxes and basket rails are free to move or expand with respect to each other. However, in the top and bottom sections of the basket assembly, stainless plate inserts are welded between the boxes to prevent the poison plates from sliding out during end drop conditions. These welded plate inserts will cause some thermal stresses in the radial and axial directions due to temperature gradients. Therefore, the following conditions are evaluated:

- In the top and bottom section of the basket assembly: Thermal stresses due to radial temperature gradients during handling/transfer for -40°F ambient, 100°F ambient and vacuum drying conditions are calculated for the DSC inside the transfer cask. Similarly, thermal stresses due to radial temperature gradients during storage/operations for -40°F ambient, 100°F ambient, 125°F ambient and vent block conditions are calculated for the DSC inside the HSM

- In the basket center (hottest section of the basket assembly): Thermal stresses in the 3 by 3 stainless steel outer wrap caused by the increase in poison plate thickness, due to thermal expansion, are calculated. (Figure K.3.4-2 (a)).

- In the basket center (hottest section of the basket assembly): Thermal stresses in the 3 by 3 stainless steel outer wrap caused by the increase in poison plate length, due to thermal expansion, are also calculated (Figure K.3.4-2 (a)).

- Thermal stresses in the center 3 by 3 outer wrap: Thermal stresses in the 3 by 3 stainless steel outer wrap caused by the axial temperature gradient are also calculated (Figure K.3.4-2 (b)).

- Thermal stress within the basket rails

- Thermal stress of the plate weld inserts

1. Thermal Stresses in the Top and Bottom of the Basket Assembly Due to Radial Thermal Gradient

A three-dimensional finite element model of the basket is used for thermal stress analyses of the basket, using ANSYS [3.11]. This finite element model is taken from the model used for the basket side drop analysis as described in Section K.3.6.1.3. Due to symmetry of the temperature distribution, only a ¼ model is used in this analysis.

The thermal analysis of the NUHOMS®-61BT DSC/basket described in Section K.4 is performed using a 3-D ANSYS model. It is seen from the temperature distribution in Section K.4, that the radial thermal gradient and temperatures at the basket bottom section are higher than those at the top section. Therefore, the temperature distribution from those analyses at bottom cross sections are used to performed the ANSYS structural analyses of the basket thermal stresses.

The maximum stress intensities from the finite element model analyses during handling/transfer for the –40°F ambient, 100°F ambient, and vacuum drying conditions (DSC in transfer cask) are summarized in the following table.

Summary of the Maximum Thermal Stress at Bottom Cross Section of the Basket Handling/Transfer

Load Case	Component	Maximum Stress(ksi)
-40°F Ambient	Basket	8.85
100°F Ambient	Basket	9.90
Vacuum Drying*	Basket	12.84

* With total decay heat loads in excess of 17.6 kW, administrative controls prevent the vacuum drying process from continuing for more than 96 hours. For conservatism in the determination of thermal stresses during the vacuum drying condition, bounding steady-state temperatures with a maximum total decay heat load of 18.3 kW are used for the evaluation.

The maximum stress intensities from the finite element model analyses during operation/storage for the –40°F ambient, 100°F ambient, 125°F ambient and blocked vent conditions (DSC in HSM) are summarized in the following table.

Summary of the Maximum Thermal Stress at Bottom Cross Section of the Basket Operation/Storage

Load Case	Component	Maximum Stress(ksi)
-40°F Ambient	Basket	6.13
100°F Ambient	Basket	8.70
125°F Ambient	Basket	8.88
Blocked Vent	Basket	15.25

2. Thermal Stresses In The 3 By 3 Stainless Steel Outer Wrap Poison Plate Thickness, Due To Thermal Expansion of Poison Plates (see Figure K.3.4-2 (a))

Stresses are induced in the stainless steel outer wraps due to differential growth of the poison plates and the stainless steel. First, the poison plates will expand through the thickness more than the stainless steel. The differential thermal growth and tensile stresses induced in the center 3 x 3 box are shown in columns 4 and 5 of the table below. Stresses in the 2 x 2 boxes and the other 3x3 boxes will be lower due to lower temperatures and/or less poison plates. In addition, the poison plate length will increase. In general, gaps are provided in the basket to allow for thermal growth of the poison plates, so that there are no thermal stresses. However, in some cases, such as during vacuum drying, the gaps will close and stresses will occur. The differential growth in the length of the poison plates (in the center 3 x 3 box) is shown in column 6 in the table below. The stresses due to this thermal growth are provided in column 8. The stresses are calculated by hand, using coefficients of thermal expansion from the ASME code for stainless steel and 6061-T6 for the aluminum poison plates.

HANDLING/TRANSFER							
Condition	Max. Basket Temp (CF)	Outer Wrapper Inside Length (in)	Diff. Thermal Growth (in x 10^{-3}) (wall thickness exp.)	Tensile Stress (ksi)	Diff. Thermal Growth (in) (poison length)	Gap (in)	Stress (ksi)
-40°F Ambient	555	19.43	1.359	1.79	.043	.05	0
100°F Ambient	615	19.43	1.564	2.03	.049	.05	0
Vacuum Drying	813*	19.43	2.257	2.8	.071	.05	1.29 (See Below)
STORAGE/OPERATIONS							
-40°F Ambient	425	19.43	0.960	1.3	0.030	0.05	0
100°F Ambient	544	19.43	1.329	1.75	0.042	0.05	0
125°F	566	19.43	1.406	1.85	0.044	0.05	0
Blocked Vent	786	19.43	2.175	2.70	0.068	0.05	1.05 (See Below)

* Using bounding steady-state temperatures for the thermal stress calculation. Administrative controls prevent the vacuum drying process continuing for more than 96 hours. The maximum basket temperature will not exceed 800 °F based on the thermal evaluation presented in Section K.4.

During vacuum drying conditions, the poison plate length will grow more than the gap provided by 0.021 inches. Assuming conservatively that the poison plate has zero deformation, each stainless steel plate will deflect by 0.011" at the poison plate location (x = 6.43" from end). The deflection at the center is estimated by modeling the plate as a beam with fixed ends and a span L = 19.43 in. ([3.12], Table III, Case 31).

$$= W/(48\ EI)\ [3L\chi^2 - 4\ \chi^3] = W/(48\ EI)\ [3x\ 19.43\ x\ 6.43^2 - 4x6.43^3]\ = 0.011$$

$$W/EI = (.011\ x\ 48)/1346.6 = 0.000392$$

Deflection at center , $y_{max} = WL^3/(192\ EI) = 0.000392\ x\ 19.43^3/192 = 0.015$ in.

Bending stresses in the stainless steel plate are estimated by modeling the plate as a beam with fixed ends having a span L = 19.43 in, thickness = 0.105 in, and deflection at center (conservative) y = 0.016 in.
$E = 24.1\times10^6$ psi

Max. Deflection, $y = W\ L^3\ /(192\ EI)$, $W = 192\ y\ EI/L^3$, Max. $M = WL/8$

$$\text{Max. Bending stress} = MC/I = WLC/8I = 192\ y\ E\ I\ LC/(L^3 \times 8 \times I) = 24\ y\ EC/L^2$$
$$= 24 \times 0.016 \times 24.1\times10^6 \times 0.0525/19.43^2 = 1{,}290 \text{ psi} = 1.29 \text{ ksi}$$

Similarly, for the blocked vent accident condition, the poison plate length will grow more than the gap provided by 0.018 inches. The maximum bending stress is calculated using the same methodology as used for the vacuum drying condition, and found to be 1.05 ksi.

3. Thermal Stresses In The 3 By 3 Stainless Steel Outer Wrap Caused By The Axial Temperature Gradient (Figure K.3.4-2 (b))

The 3 by 3 box is hot at the center cross section and cooler at the top and bottom cross sections. This axial gradient will result in unequal thermal expansion at the center and top or bottom of the basket (see Fig. K.3.4-2b), causing bending stresses in the outer stainless steel wrap. The stresses in the other 3 x 3 boxes and the 2 x 2 boxes will be lower due to lower temperatures further from the center of the basket. The thermal stresses are calculated for the -40°F ambient condition below. The remainder of the cases are evaluated in the same manner and tabulated below.

For the -40° F Ambient Normal Condition, the temperatures of interest in the basket are:

Maximum temperature at center = 555° F
Minimum temperature at top = 448° F

α_S = Stainless steel coefficient of thermal expansion = 9.45×10^{-6} in./in.°F at 550°F
α_S = Stainless steel coefficient of thermal expansion = 9.28×10^{-6} in./in.°F at 450°F
$L = 19.43 + 2 \times 0.105 = 19.64$ in.

At center, thermal growth, $\delta L_1 = 19.64 \times (555 - 70) \times 9.45 \times 10^{-6} = 0.09002$ in.
At top, thermal growth, $\delta L_2 = 19.64 \times (448 - 70) \times 9.28 \times 10^{-6} = 0.06889$ in.
Therefore, plate deflection on either side of box = ½ (0.09002 - 0.06889) = 0.0106 in.

Stresses are calculated by modeling the side of the box as a plate 19.64 in × 164 in fixed on all sides ([3.12], Table X, Case 41):

a = 164" **b = 19.64"** **a/b = 8.35** **α =0.0284** **β = 0.5** **β/α = 17.606**

Max. Deflection $y = \alpha\, wb^4/(Et^3)$ $w = yEt^3 / \alpha\, b^4$ E, at 450° F = 26.2×10^6

At center of long edge, the maximum stress is calculated as follows:

$s = \beta\, wb^2 / t^2 = (\beta/\alpha) \times [yEt/b^2]$
$= (17.606)\,[0.0106 \times 26.2 \times 10^6 \times 0.105/19.64^2] = 1{,}331$ psi ≈ 1.33 ksi

Thermal Stresses in Center 3 x 3 Stainless Steel Outer Wrap due to Axial Thermal Gradient

Condition	Max T(°F) at Center	Min T(°F) at Top	Plate Deflection	Max Stress (ksi)
HANDLING/TRANSFER				
-40°F Ambient	555	448	0.0106	1.33
100°F Ambient	615	510	0.0107	1.32
Vacuum Drying	813	691	0.0128	1.53
OPERATION/STORAGE				
-40°F Ambient	425	310	0.011	1.42
100°F Ambient	544	435	0.0109	1.37
125°F	566	458	0.0107	1.34
Blocked Vent	786	695	0.0096	1.14

4. Summary of Basket Compartment Thermal Stresses

The following table summarizes and combines the thermal stresses calculated above. The combination is conservative, since the maximum stresses due to each individual case at different basket locations are added, irrespective of their locations.

Summary of Thermal Stresses in Basket Compartment

Loading Condition	**Stress due to radial thermal gradient (ksi) (bottom)**	**Stress due to poison plate thickness growth (ksi) (center)**	**Stress due to poison plate length growth (ksi) (center)**	**Stress due to axial thermal gradient (ksi) (center)**	**Combined Stress (ksi)**
HANDLING/TRANSFER					
-40° F Ambient	8.85	1.79	0	1.33	11.97
100° F Ambient	9.9	2.03	0	1.32	13.25
Vacuum Dry	12.84	2.80	1.29	1.53	18.46
OPERATION/STORAGE					
-40° F Ambient	6.13	1.30	0	1.42	8.85
100° F Ambient	8.70	1.75	0	1.37	11.82
125° F Ambient	8.88	1.85	0	1.34	12.07
Blocked Vent	15.25	2.70	1.05	1.14	20.14

B. Thermal Stress Analysis of the Basket Rails

Thermal stresses can only be developed in the rails if their free thermal expansion is constrained by the DSC/basket. The basket rails are free to grow in all thermal loading conditions. The rails are attached to the basket with bolts in slotted holes. Thus the rails are permitted to grow relative to the basket boxes. Therefore, only thermal stresses in the rail, due to temperature gradients in the rail cross section, are considered.

It is seen from the thermal analysis presented in Section K.4 that the thermal gradient in the Type 1 rails are higher than in Type 2 rails. A three-dimensional finite element model of the Type 1 rail was extracted from the ANSYS three dimensional basket finite element model (See K.3.6.1.3) and is used for thermal and stress analyses of the rail. The four-node element SHELL57 (Thermal Shell) was used in the thermal analysis. It was replaced by stress element SHELL43 for this analysis.

The steady-state thermal analyses of the rail are conducted to obtain the nodal temperatures in the model by impressing the temperatures (taken from Section K.4) as the boundary conditions for the above three thermal loading conditions.

The thermal stresses are calculated due to nodal temperature distributions from the above thermal analyses. The results for the handling/transfer and operation storage thermal loading conditions are summarized in the following table.

Summary of Thermal Stresses in Basket Rail

Case	Loading Condition	Maximum Membrane plus Bending Stress Intensity(ksi)
Handling /Transfer	-40° F Ambient	0.81
	100° F Ambient	1.01
	Vacuum Drying	0.83
Operation/ Storage	-40° F Ambient	0.91
	100° F Ambient	0.78
	125° F Ambient	0.79
	Blocked Vent	0.89

C. Thermal Stress Analysis of Basket Plate Inserts

Basket plate inserts are welded to the top and bottom of the of the NUHOMS® 61B basket to prevent the aluminum poison plates from sliding in the axial direction. The geometry of the basket plate inserts is shown on drawing NUH-61B-1064, provided in Section K1.5. The critical locations with respect to thermal stress are in the insert weld locations, since the weld is used to hold the basket plate insert and basket outer wrappers together.

In the basket plate insert regions (at the top and bottom of the basket), there are no poison plates. Therefore, the only thermal stress generated in the insert welds is caused by the differential thermal expansion of the outer wrappers due to the radial temperature gradient of the basket.

In the analysis below, the average temperature of the adjacent 4 compartment, and 9 compartment outer wrappers are found from the thermal analysis from Section K.4 and used to compute the difference in thermal expansion between the two outer wrappers. The highest temperature load cases for the handling/transfer and operation/storage conditions are the vacuum drying condition and blocked vent condition, respectively. These two cases are analyzed below since they are the bounding load cases.

1. Vacuum Drying Case

From the ANSYS results file generated in Section k.4, the average outer wrapper temperatures are computed below.

9 compartment wrapper location average temperature is 630° F.

4 compartment wrapper location average temperature is 623° F.

α_S = Stainless steel coefficient of thermal expansion = 9.61×10^{-6} in./in.°F
E = Stainless steel modulus of elasticity = 25.05×10^6 psi

The length of the outer wrapper analyzed, L, is,

$$L = 3\times6 + 3 + 4\times0.12 + 3\times0.105 + 3\times0.31 + 3\times0.135 = 23.13 \text{ in.}$$

Differential thermal growth, δL, is

$$\delta L = L \times [\,(632\text{-}70) - (623\text{-}70)\,]\,(\alpha_s)$$
$$= 23.13 \times [\,(632\text{-}70) - (623\text{-}70)\,]\,(9.61 \times 10^{-6}) = 2001\times10^{-6} \text{ in.}$$

The pressure generated in the outer wrappers by this differential growth, P, is,

$$P = \varepsilon E = \delta L/L \times E = 2001\times10^{-6} / 23.13 \times 25.05\times10^{6} = 2166.6 \text{ psi.}$$

Assuming that the pressure in the outer wrapper acts over an area equal to 0.105 in. thick × 3.50 in. tall (size of weld insert), then the force applied to the basket plate insert welds, F, is

$$F = (0.105 \times 3.50) \times 2166.6 = 796.2 \text{ lb.}$$

The shear area of the welds, $A = (0.125 \text{ in.} \times \sin(45)) \times 1 \text{ in.} \times 16 \text{ welds} = 1.414 \text{ in.}^2$
Therefore the shear stress in the weld, $\tau = 796.2 \text{ lb.} / 1.414 \text{ in.}^2 = 563 \text{ psi.} \approx 0.56 \text{ ksi}$

2. Blocked Vent Condition

From the ANSYS results file generated in Section K.4, the average outer wrapper temperatures are computed below.

9 compartment wrapper location average temperature is 681° F.

4 compartment wrapper location average temperature is 682° F.

α_S = Stainless steel coefficient of thermal expansion = 9.69×10^{-6} in./in.°F
E = Stainless steel modulus of elasticity = 24.8×10^6 psi at 700°F

The length of the outer wrapper analyzed, L, is,

$$L = 3 \times 6 + 3 + 4 \times 0.12 + 3 \times 0.105 + 3 \times 0.31 + 3 \times 0.135 = 23.13 \text{ in.}$$

Differential thermal growth, δL, is
$\delta L = L \times [\,(682\text{-}70) - (681\text{-}70)\,]\,(\alpha_s)$
$= 23.13 \times [\,(682\text{-}70) - (681\text{-}70)\,]\,(9.69 \times 10^{-6}) = 224 \times 10^{-6}$ in.

The pressure generated in the outer wrappers by this differential growth, P, is,
$$P = \varepsilon E = \delta L/L \times E = 224{\times}10^{-6} / 23.13 \times 24.8{\times}10^{6} = 240.31 \text{ psi.}$$

Assuming that the pressure in the outer wrapper acts over an area equal to 0.105 in. thick × 3.50 in. high (size of weld insert), then the force applied to the basket plate insert welds, F, is

$$F = (0.105 \times 3.50) \times 240.31 = 88.31 \text{ lb.}$$

The shear area of the welds, $A = (0.125 \text{ in.} \times \sin(45)) \times 1 \text{ in.} \times 16 \text{ welds} = 1.414 \text{ in}^2$

Therefore the shear stress in the weld, $\tau = 88.31 \text{ lb.} / 1.414 \text{ in.}^2 = 62 \text{ psi} \approx 0.06 \text{ ksi}$

D. Summary of the Basket Assembly Thermal Stresses

The following table summarizes the basket assembly thermal stresses due to the handling/transfer and storage/operations thermal loads.

Summary of the Basket Assembly Thermal Stresses

THERMAL LOADING	MAXIMUM CALCULATED THERMAL STRESS (KSI)		
	Basket	**Rail**	**Plate Insert**
Handling/Transfer			
-40°F Ambient	11.97	0.81	Enveloped by Vacuum Drying Condition
100°F Ambient	13.25	1.01	Enveloped by Vacuum Drying Condition
Vacuum Drying	18.46	0.83	0.56
Storage/Operations			
-40°F Ambient	8.85	0.91	Enveloped by Blocked Vent Condition
100°F Ambient	11.82	0.78	Enveloped by Blocked Vent Condition
125°F Ambient	12.07	0.79	Enveloped by Blocked Vent Condition
Blocked Vent	20.14	0.89	0.06

These stresses are well below the allowable stresses permitted by the ASME B&PV Code (3 S_m, 3 x 15.2 = 45.2 ksi, S_m at 800°F) and are combined with other loads in Section 3.6.1.3.3 for handling/transfer loads and Section 3.6.1.3.4 for operation/storage loads.

POTENTIAL VERSUS pH DIAGRAM FOR ALUMINUM-WATER SYSTEM

At 25°C (77°F):

At 60°C (140°F):

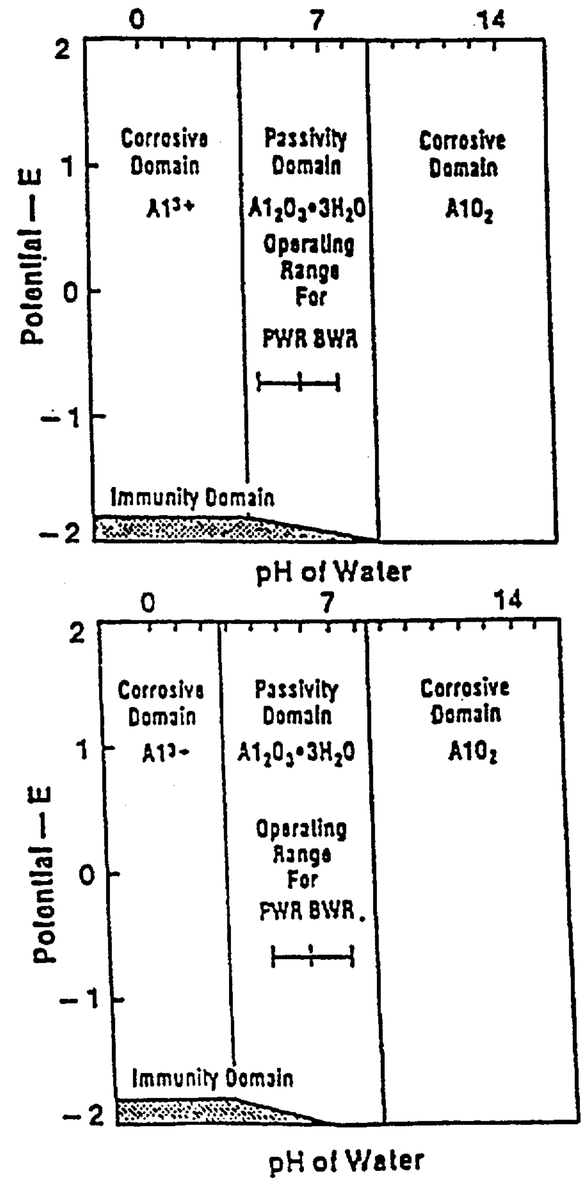


Figure K.3.4-1
Potential Versus pH Diagram for Aluminum-Water System

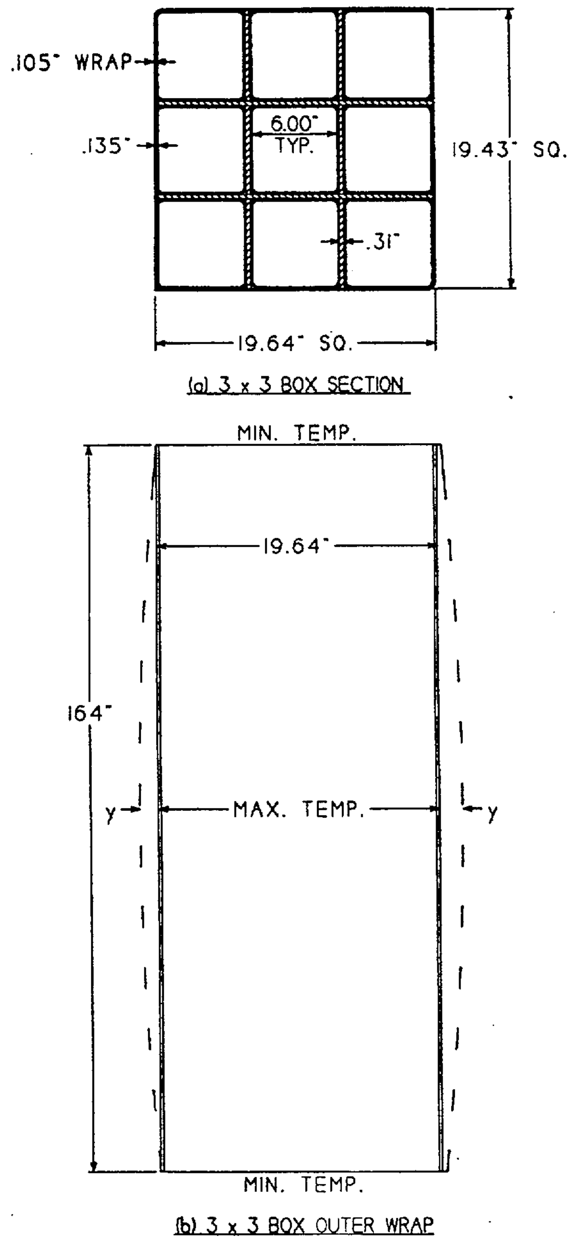


Figure K.3.4-2
Thermal Stress Analysis Geometry

K.3.5 Fuel Rods

No Change to the evaluation presented in the CSAR.

K.3.6 Structural Analysis (Normal and Off-Normal Operations)

In accordance with NRC Regulatory Guide 3.48 [3.13], the design events identified by ANSI/ANS 57.9-1984, [3.14] form the basis for the accident analyses performed for the standardized NUHOMS® system. Four categories of design events are defined. Design event Types I and II cover normal and off-normal events and are addressed in Section 8.1 of the CSAR. Design event Types III and IV cover a range of postulated accident events and are addressed in Section 8.2 of the CSAR. The purpose of this section of the Appendix is to present the structural analyses for normal and off-normal operating conditions for the NUHOMS®-61BT system using a format similar to the one used in CSAR Section 8.1 for analyzing the NUHOMS® 52B system.

K.3.6.1 Normal Operation Structural Analysis

Table K.3.6-1 shows the normal operating loads for which the NUHOMS® safety-related components are designed. The table also lists the individual NUHOMS® components which are affected by each loading. The magnitude and characteristics of each load are described in Section K.3.6.1.1.

The method of analysis and the analytical results for each load are described in Sections K.3.6.1.2 through K.3.6.1.9.

K.3.6.1.1 Normal Operating Loads

The normal operating loads for the NUHOMS® system components are:

1. Dead Weight Loads
2. Design Basis Internal and External Pressure Loads
3. Design Basis Thermal Loads
4. Operational Handling Loads
5. Design Basis Live Loads

These loads are described in detail in the following paragraphs.

A. Dead Weight Loads

Table K.3.2-1 shows the weights of various components of the NUHOMS® -61BT system. The dead weight of the component materials is determined based on nominal component dimensions.

B. Design Basis Internal and External Pressure

The maximum internal pressures of the NUHOMS®-61BT DSC for the storage and transfer mode are presented in Table K.4-5.

C. Design Basis Thermal Loads

The temperature distribution for the DSC shell assembly for the normal conditions is presented in Section K.4.0 and the resulting thermal loads are addressed in Section K.3.4.

D. Operational Handling Loads

There are two categories of handling loads: (1) inertial loads associated with on-site handling and transporting the DSC between the fuel handling/loading area and the HSM, and (2) loads associated with loading the DSC into (and unloading the DSC from) the HSM. These handling loads are described in CSAR Section 8.1.1.1C.

Based on the surface finish and the contact angle of the DSC support rails inside the HSM described in Chapter 4 of the CSAR, a bounding coefficient of friction is conservatively assumed to be 0.25. Therefore, the nominal ram load required to slide the DSC under normal operating conditions is approximately 25,633 lbs, calculated as follows:

$$P = \frac{0.25\ W}{\text{Cos}\ \theta} = 0.29\ W = 0.29(88{,}390\ \text{lbs}) = 25{,}633\ \text{lbs} \qquad (8.1\text{-}1)$$

Where:

P = Push/Pull Load

W = Loaded DSC Weight ≈ 88,390 lbs (SeeTable K.3.2-1)

θ = 30 degrees, Angle of the Canister Support Rail

However, the DSC bottom cover plate and grapple ring assembly are designed to withstand a normal operating insertion force equal to 80,000 pounds and a normal operating extraction force equal to 60,000 pounds. To insure retrievability for a postulated jammed DSC condition, the ram is sized with a capacity for a load of 80,000 pounds, as described in Section 8.1.2 of the CSAR. These loads bound the friction force postulated to be developed between the sliding surfaces of the DSC and transfer cask during worst case off-normal conditions.

E. Design Basis Live Loads

As discussed in Section 3.2.4 of the CSAR, a live load of 200 pounds per square foot is conservatively selected to envelope all postulated live loads acting on the HSM, including the effects of snow and ice. Live loads which may act on the transfer cask are negligible, as discussed in Section 3.2.4 of the CSAR.

K.3.6.1.2 Dry Shielded Canister Analysis

The standardized NUHOMS®-61BT DSC shell assembly is analyzed for the normal, off-normal and postulated accident load conditions using two basic ANSYS [3.11] finite element models: a top-end half-length model of the DSC shell assembly and a bottom-end half-length model of the DSC shell assembly. Typical models of the top and bottom halves of the DSC shell assembly are shown in Figure 8.1-14a and Figure 8.1-14b of the CSAR.

These models are used to evaluate stresses in the NUHOMS®-61BT DSC due to:

1. Dead Weight
2. Design Basis Normal Operating Internal and External Pressure Loads
3. Normal Operating Thermal Loads
4. Normal Operation Handling Loads

The methodology used to evaluate the effects of these normal loads is addressed in the following paragraphs. Table K.3.6-4 summarizes the resulting stresses for normal operating loads.

A. DSC Dead Load Analysis

Dead load analyses of the DSC are performed for both vertical and horizontal positions of the DSC. In the vertical position, the DSC shell supports its own empty weight and the entire weight of the top end components. When inside the Transfer Cask, the weight of the fuel and the bottom end components is transferred to the Transfer Cask by bearing through the inner cover plate, shield plug and outer bottom cover plate. When in the horizontal position, the DSC is in the Transfer Cask or in the HSM. In this position, the DSC shell assembly end components and the internal basket assembly bear against the DSC shell. The DSC shell assembly is supported by two rails located at ± 18.5° (when in the Transfer Cask) and ± 30° (when in the HSM) from the bottom centerline of the DSC. This is shown schematically in Figure 8.1-13 of the CSAR.

Dead load stresses are obtained from static analyses performed using the ANSYS finite element models described above. Both, the top-end half and bottom-end half models are analyzed for a 1g load, using the appropriate finite element model and boundary conditions, for horizontal and vertical configurations. For the horizontal dead load analyses, the DSC is conservatively assumed to be supported on one rail. In addition, the fuel-loaded portions of the basket assembly bear on the inner surface of the DSC shell. DSC shell stresses in the region of the basket assembly resulting from the bearing load and from local deformations at the cask rails are evaluated using the ANSYS model described in Section K.3.6.1.3. The DSC shell assembly components are evaluated for primary membrane and membrane plus bending stress and for primary plus secondary stress. Enveloping maximum stress intensities are summarized in Table K.3.6-4 for the NUHOMS®-61BT DSC.

B. DSC Normal Operating Design Basis Pressure Analysis

The 61BT DSC shell assembly analytical models shown in Figure 8.1-14a and Figure 8.1-14b of the CSAR are used for the normal operating design pressure analyses. The calculated maximum internal pressures for the NUHOMS®-61BT DSC are shown in Table K.4-5. The resulting maximum stress intensities are reported in Table K.3.6-4.

C. DSC Normal Operating Thermal Stress Analysis

The thermal analysis of the DSC for the various conditions, as presented in Section K.4.0, provide temperature distributions for the DSC shell, along with maximum and minimum DSC component temperatures. These temperature distributions are imposed onto the DSC shell assembly ANSYS stress analysis models shown in Figure 8.1-14a and Figure 8.1-14b of the CSAR for thermal stress evaluation. Maximum component temperatures are used to determine material properties and stress allowables used in the stress analysis. DSC shell assembly materials are all SA 240 Type 304 stainless steel with the exception of the shield plugs, which are made of A-36 carbon steel. However, because these dissimilar materials are not mechanically fastened, allowing free differential thermal growth, the thermal stresses in the DSC shell components are due entirely to thermal gradients. The results of the thermal analysis show that for the range of normal operating ambient temperature conditions, the thermal gradients are primarily along the axial and tangential directions of the DSC and that no significant thermal gradients exist through the wall of the DSC. Stresses resulting from thermal gradients are classified as secondary stresses and are evaluated for Service Level A and B conditions. Maximum stress intensities resulting from the thermal stress analyses are summarized in Table K.3.6-4 for the NUHOMS®-61BT DSC.

D. DSC Operational Handling Load Analysis

To load the DSC into the HSM, the DSC is pushed out of the transfer cask using a hydraulic ram. The applied force from the hydraulic ram, specified in Section 3.6.1.1.1 of the CSAR, is applied to the center of the DSC outer bottom cover plate at the center of the grapple ring assembly. The ANSYS finite element model shown in Figure 8.1-14b of the CSAR is used to calculate the stresses in the DSC shell assembly. In the analysis, the ram load is applied to the cover plate in the form of two arcs, assuming that the load is concentrated at the barrel diameter of the ram, excluding the cutouts for extension of the grapple arms.

To unload the HSM, the DSC is pulled using grapples which fit into the grapple ring. For analysis of grapple pull loading, the 180° ANSYS finite element model of the bottom half DSC assembly is refined in the area of the grapple assembly and outer cover plate, as shown in Figure 8.1-15 of the CSAR.

The controlling stresses from these analyses are tabulated in Table K.3.6-4.

E. Evaluation of the Results

The maximum calculated DSC shell stresses induced by normal operating load conditions are shown in Table K.3.6-4. The calculated stresses for each load case are combined in accordance with the load combinations presented in Table K.3.7-15 of the CSAR. The resulting stresses for the controlling load combinations are reported in Section K.3.7.10 with the ASME Code allowable stresses.

K.3.6.1.3 NUHOMS®-61BT Basket Structural Analysis

A three dimensional ANSYS finite element model is used to evaluate the stresses in the basket assembly due to the following individual load cases:

- Dead Weight
- Thermal Stress calculation
- Handling/Transfer Loads
- Side Drop Loads
- Seismic Loads

The thermal loads for the basket are addressed in Section K.3.4. The side drop loads are Level D loads and are addressed in Section K.3.7. The seismic loads are level C loads but have been used to envelope the normal horizontal dead weight as described in Section K.3.6.1.3.2. Hence, the basket stress analysis for the seismic load is presented in Section K.3.6 instead of K.3.7.

K.3.6.1.3.1 ANSYS Finite Element Model Analysis

A. ANSYS Finite Element Model Description

A three-dimensional finite element model of the basket, rails and canister is constructed using SHELL 43 elements. The basket and rail model dimensions are based on drawings NUH-61B-1063, -1064, and -1065. The overall finite element model of the basket, rails and canister is shown in Figure K.3.6-1. For conservatism, the strength of poison plates was neglected by excluding these from the finite element model. However, their weight is accounted for by increasing the stainless steel basket plate density. Because of the large number of plates in the basket and large size of the basket, certain modeling approximations are necessary. In view of continuous support of plates by rails along the entire length during a side drop, only a 3" long slice of the basket, rail and canister is modeled. At the two cut faces of the model, symmetry boundary conditions were applied (UZ = ROTX = ROTY=0). The fuel compartment tubes, outer 3 x 3 and 2 x 2 boxes, and rails are included in the model and are shown individually in Figures K.3.6-2 to K.3.6-4. The basket and canister are analyzed for two modes of side drop. For each drop mode, the gap elements between the outside of the canister and inside of the transfer cask are simulated as follows:

Impact Away From The Transfer Cask Support Rails (Figure K.3.6-5, 45°, 60° and 90°)

The gap elements (CONTACT 52) are used to simulate the interface between the basket rails and the inner side of the canister as well as between the outer side of the canister and inside of the cask. Each gap element contains two nodes; one on each surface of the structure. The gap nodes specified at the inner side of cask are restrained in the x, y and z directions. The gap size at each gap element is determined by the difference between the basket rails radius and the inside radius of the cask inner shell; and by the difference between the outer side of canister radius and the inside radius of the canister. Gap sizes for the gap elements, at each radial location, are determined and input into the model as real constants using a small ANSYS macro. This macro accepts the drop orientation and model geometry as inputs and then determines the circumferential position of each gap element. The macro then computes the appropriate real constants and applies to appropriate gap elements. The gap sizes between the rails and the canister; and canister and cask (over 5° interval up to 90° and 10° interval beyond) are shown in Figures K.3.6-6 and Figure K.3.6-7. The finite element model of the canister and gaps is shown in Figures K.3.6-8 and Figure K.3.6-9.

Impact On Transfer Cask Support Rails (Figure K.3.6-5, 161.5°, and 180°)

During drops on the transfer cask support rails (161.5° and 180° side drops), the initial gaps between the canister and the cask are modified. The gaps at the rail locations are assumed closed. In between the rail locations, initial gaps are assumed as 0.12". The remaining initial gaps are suitably modified (0.12" to 0.63") using the ANSYS macro.

The connections between the stainless steel fuel compartment square tubes (with intermediate aluminum poison plates), between the tubes and outer stainless steel boxes, and between the outer boxes and stainless steel rails are made with node couplings. The nodes of various plates are coupled together in the out-of-plane direction so that they will bend in unison under surface pressure or other lateral loadings and to simulate through-the- thickness support provided by the poison plates. The bolt connections between the rail members and outer boxes are also simulated by node couplings. During each side drop orientation, some fuel boxes and rails may have a tendency to separate or slide. Gap elements were used to model the connections at such locations. The coupling and gaps between the basket and the transfer cask rails were appropriately modified to suit individual basket drop orientation. During 90 and 180 degree side drops, the basket is symmetric about the drop axis. Thus, only a one-half finite element model is used in this analysis.

B. Material Nonlinearities

The basket, basket rails and canister are constructed from SA-240, 304 stainless steel. A bilinear stress strain relationship was used to simulate the correct nonlinear material behavior. The following elastic and inelastic material properties are used in the analysis:

SA-240, 304 Stainless Steel	500°F
Modulus of Elasticity, E(psi)	25.8×10^6
Yield Strength(psi)	19,400
Tangent Modulus,E_t(psi)	5% of E = 1.29×10^6

The material properties used in the analysis are at 500°F. However, the resulting stresses are compared with the allowables at 650°F. This combination is considered conservative because using lower values of E, S_y and E_t (at 650°F) in the analysis would result in lower stresses. Also, because of higher displacements, more gaps would close, resulting in further lowering the stresses.

C. Gap Element Nonlinearities

Gap elements (Contact 52) are used to model the actual surface clearance between the basket rails and canister inside as well as between the canister outside and cask inside. The gap elements introduce nonlinearities in the analysis depending upon whether they are open or closed. The typical gap sizes are shown in Figures K.3.6-6 and K.3.6-7. Actual gap sizes at each rail nodal location are computed using an ANSYS macro. The gap element spring constant, K_n, is calculated as:

$K_n = f E h$ [3.11]

Where

f = A factor usually between 0.01 to 100h
E = Modulus of elasticity (25.8×10^6 psi)
h = In a 3-D model, h should be a typical 'target length' or typical element size

Typical element length $\approx$ 1.16 in.
Typical target length = $(1.16 \times 3.0)^{0.5} = 1.86$ in.

$K_n = 25.8 \times 10^6 \times 1.860 \times f = 0.48 \times 10^6$ to 4800×10^6 lb/in

In view of the large range in spring constant values, different spring constants are evaluated. The structure responded well for a spring constant value of 0.5×10^6 lb/in. and was used in the final runs. Further, to help convergence, ANSYS elements LINK8 were inserted coincident to the CONTACT52 elements. To assure that these elements do not transfer a substantial load between the surfaces, a very low elastic modulus (E =1000 psi for radial gaps and E = 100 psi for gaps between boxes), a small area (0.1 in^2) and zero density (to zero their inertial loading contribution to the structure) were used in the analyses.

K.3.6.1.3.2 Loadings

Postulated basket load conditions are described below.

A. Handling/Transfer Loads

The basket handling/transfer loads are summarized in the table below. As seen in the table, smaller loads are conservatively lumped with bigger loads to minimize the analysis effort.

Basket Loads in Transfer Cask (Handling/Transfer Loads)

Loading	Basket Orientation	Service Level	Load	Enveloped Load for Analysis
Dead Weight	Vertical	A	1g Down (Axial)	1g Down (Axial)
Thermal	Vertical	A	Vacuum Drying	Vacuum Drying
Dead Weight	Horizontal	A	1g Down	2g Axial + 2g Trans. + 2g Vertical
Handling Load in Transfer Cask	Horizontal	A	DW + 1g Axial DW + 1g Trans. DW + 1g Vert. DW + 0.5g Axial+ 0.5 Trans.+ 0.5 Vert.	2g Axial + 2g Trans. + 2g Vertical + Thermal
Thermal(2)	Horizontal	A B	100°F Ambient -40°F Ambient	100°F Ambient(1) -40°F Ambient
Side Drop(3)	Horizontal	D	75g in Multiple Orientations	75g in Multiple Orientations(45°, 60°, 90°, 161.5° and 180°)
Corner Drop(3)	Horizontal	D	25g Corner Drop	Enveloped by 75g Side Drop and 75 g End Drop
End Drop(3)	Vertical	D	75g End Drop	75g End Drop

(1) This case envelopes the case when the DSC is being transferred within the OS 197 Cask at 125°F with a sunshade.
(2) The thermal stresses of the basket are addressed in Section K.3.4.
(3) Level D loads are addressed in Section K.3.7.

B. Operation/Storage Loads

The basket loads in the Horizontal Storage Module (HSM) are summarized in the table below. As seen in the table, smaller loads are also conservatively lumped with bigger loads to minimize the analysis effort.

Basket Loads in HSM (Operation/Storage Loads)

Loading	Basket Orientation	Service Level	Load	Enveloped Load for Analysis
Dead Weight	Horizontal	A	1g Down	2g Axial + 2g Trans. +2g Vertical
Seismic Loads	Horizontal	C	0.37g Axial+ 0.37g Trans.+0.17g Vertical	2g Axial + 2g Trans. + 2g Vertical + Thermal
Thermal(1)	Horizontal	B A B	-40°F Ambient 100°F Ambient 125°F Ambient	-40°F Ambient 100°F Ambient 125°F Ambient
Thermal(1)	Horizontal	D	Blocked Vent	Blocked Vent

(1) The thermal stresses of the basket are addressed in Section K.3.4.

K.3.6.1.3.3 Basket Stress Analysis due to Handling /Transfer Loads

A. Vertical Dead Weight (Basket in Vertical Orientation)

During the1g down loading, the fuel assemblies and fuel compartment are forced against the bottom of the cask. It is important to note that, for any vertical or near vertical loading, the fuel assemblies react directly against the bottom of the canister/cask and not through the basket structure as in lateral loading. It is the dead weight of the basket that causes axial compressive stress during an end drop. Axial compressive stresses are conservatively computed assuming all the weight is taken by the compartment tubes and outer stainless steel wrappers. A conservative basket weight of 23.0 kips (actual weight is 22.92 kips) is used in this analysis.

Compressive Stress at Fuel Compartment Tubes and Outer Wrappers

Total weight = 23.0 kips
Weight excluding hold down ring, SS plate inserts, poison plates, aluminum plates, and rails is calculated to be 12.49 kips

Section area = 12,490 /(164 x 0.29) = 262.62 in^2
Stress due to 1g = -23.0 / 262.62 = - 0.09 ksi

Compressive Stress on Holddown Ring

Weight of hold down ring = 0.94 kips
Section area = 940/(14.5 x 0.29) = 223.5 in^2

Stress due to 1g = -23.0 / 223.5= - 0.1 ksi

This is conservative since for the 1g down case, the basket weight is not applied to the holddown ring.

Shear Stress in Plate Insert Weld

64 (total 128) Inserts support the poison plate weight (3.26 kips)

Load/insert = 3.26 / 64 = 0.051 kips
Weld Shear Area = 0.707 x 4 x 0.125 = 0.3535 in^2
Shear stress (1g) = 0.051 / 0.3535 ≈ 0.15 ksi

Shear Stress in Rail Stud

During the 1g down loading, the rail will support its own weight. However, the analysis conservatively assumes that the weight of the rail is supported by the rail studs attached to the fuel compartment tube outer wrappers.

Weight of rails = 5.35 kips
Weld Shear Area = $\pi/4\ (0.5^2 - 0.3^2) = 0.126\ in^2$
Shear stress (1g) = 5.35 / (0.126 × 224) = 0.19 ksi

B. Handling /Transfer Loads – 2g Axial + 2g Transverse + 2g Vertical (Basket in Horizontal Orientation)

The basket finite element model described in Section K.3.6.1.3.1 is used to perform the stress calculations. Since the combined loading (2g axial + 2g transverse + 2g vertical) is non-symmetric, a 360-degree model was used. The canister shell is resting on two rails inside the transfer cask (3" wide x 0.12" thick continuous pad) at 18.5° on either side of basket/canister centerline (see Figure K.3.6-5). The radial contact elements at the two pad locations are assumed closed. The canister nodes at one location of the pad are held in the circumferential direction to avoid rigid-body motion of the model. The contact elements between the pads (between canister and cask from 161.5° to 198.5°) are assumed open with a 0.12" initial gap. The remaining initial gaps are suitably modified (from 0.12"- between 161.5° & 198.5° to 0.63" – at 0°) using the ANSYS macro. The gap elements between the inside surface of the canister and the basket rails are assumed closed at 180° orientation, and remaining initial gaps are suitably modified (from 0 in. at 180°-bottom to 0.25 in. at 0° - top).

Loadings

The 2g vertical load and 2g transverse lateral load resulting from the fuel assembly weight are applied as pressures on the horizontal and vertical faces of plates.

The inertial load due to the basket, rails and canister dead weight is simulated using the density and appropriate 2g acceleration in the vertical and transverse directions. The poison plate weight is included by increasing the basket plate density. Since only a 3" length of the basket assembly is modeled, the acceleration in the axial direction is increased to account for the entire 164" length.

To simulate the axial stress due to the above acceleration, only one side of basket is restrained in the Z – direction.

Analysis and Results

A nonlinear stress analysis is conducted for computing the elastic stresses in the basket model. The nonlinearity of analysis is due to the gaps in the model. The total load is applied in mall steps. The automatic time stepping program option "Autots" is activated. This option lets the program decide the actual size of the load-substep for a converged solution. Displacements, stresses and forces at the final load substep are written to ANSYS result files. Maximum nodal stress intensities in the basket, rails and canister are shown in Figure K.3.6-10 through Figure K.3.6-15 and summarized in the following table.

Stress Summary of the Basket Due to Handling/Transfer Loads

(2g Axial + 2g Transverse + 2g Vertical)

Component	Stress Classification	Stress (ksi)	Reference Figure
Basket	P_m	0.8	K.3.6-10
	$P_m + P_b$	3.67	K.3.6-11
Rail	P_m	1.18	K.3.6-12
	$P_m + P_b$	5.11	K.3.6-13
Canister	P_m	0.7	K.3.6-14
	$P_m + P_b$	7.12	K.3.6-15

C. Summary of Basket Assembly Stress Analysis due to Handling/Transfer Loads

The following table summarizes the basket assembly stress analysis due to the handling/transfer loads. Stresses in the basket assembly due to side drop and end drop accident loads are calculated in Section K.3.7.5.3.

Summary of Basket Structural Analysis due to Handling/Transfer Load Conditions

Loading	Component	Service Level	Stress Classification	Loads	Stress (ksi)	Allowable Stress (ksi)
Vertical Dead Weight	Basket	A	P_m	1g Axial	0.09	16.2
		A	$P_m + P_b$	1g Axial	0.09	24.3
		A	$P_m + P_b + Q$	1g Axial +Thermal	18.55	45.6*
	Plate Insert	A	Shear Stress	1g Axial	0.15	9.72
		A	Shear Stress	1g Axial + Thermal	0.71	45.6
	Rails Stud	A	Shear Stress	1g Axial	0.19	9.72
Horizontal Dead Weight	Basket, Rails, Canister	A	P_m	1g Axial	Enveloped by Handling /Transfer Load	
		A	$P_m + P_b$	1g Axial		
		A	$P_m + P_b + Q$	1g Axial + Thermal		
Handling /Transfer Load	Basket	A	P_m	2g Axial,Vert.,Trans	0.8	16.2
		A	$P_m + P_b$	2g Axial,Vert.,Trans	3.67	24.3
		A	$P_m + P_b + Q$	2g Axial,Vert.,Trans + Thermal	16.92	48.6
	Rails	A	P_m	2g Axial,Vert.,Trans	1.18	16.2
		A	$P_m + P_b$	2g Axial,Vert.,Trans	5.11	24.3
		A	$P_m + P_b + Q$	2g Axial,Vert,,Trans + Thermal	6.12	48.6
	Canister	A	P_m	2g Axial,Vert.,Trans	0.7	16.2
		A	$P_m + P_b$	2g Axial,Vert.,Trans	7.12	24.3
		A	$P_m + P_b + Q$	2g Axial,Vert,,Trans + Thermal	7.12	48.6

*Allowable at temperature during vacuum drying (≈ 800° F)

K.3.6.1.3.4 Basket Stress Analysis due to Operation/Storage Loads

A. Horizontal Dead Weight

The 1g down loading is enveloped by the seismic loads.

B. Seismic Loads

Finite Element Model Analysis of the Basket Due to Seismic Load

The basket finite element model described in Section K.3.6.1.3.1 is used to perform the stress calculations. Since the combined loading (2g axial + 2g transverse + 2g vertical) is non-symmetric, a 360-degree model is used. The canister shell is resting on two rails inside the HSM (3 in. wide x 0.1875 in. thick) at 30° on either side of the basket/canister centerline. The radial contact elements at the two rail locations are assumed closed. The canister nodes at one location of the rail are held in the circumferential directions to avoid rigid-body motion of the model. The gap elements between the inside surface of the canister and the basket rails are assumed closed at the 180° orientation, and remaining initial gaps are suitably modified (from 0 in. at 180° - bottom to 0.25 in. at 0° - top).

Loadings

The 2g vertical load and 2g transverse lateral load, resulting from the fuel assembly weight are applied as pressure on the horizontal and vertical faces of plates.

The inertia load due to the basket, rails and canister dead weight is simulated using the density and appropriate 2g acceleration in the vertical and transverse directions. The poison plate weight is included by increasing the basket plate density. Since only a 3 in. length of the basket is modeled, the acceleration in the axial direction is increased to account for the entire 164" length.

To simulate the axial stress due to the above acceleration, only one side of the basket is restrained in the Z – direction.

Analysis and Results

A nonlinear stress analysis is conducted for computing the elastic stresses in the basket model. The nonlinearity of analysis is due to the gaps in the model. The total load was applied in small steps. The automatic time stepping program option "Autots" is activated. This option lets the program decide the actual size of the load-substep for a converged solution. Displacements, stresses and forces at the final load substep are written on ANSYS result files. Maximum nodal stress intensities in the basket, rails and canister are shown on Figures K.3.6-16 through K.3.6-21 and summarized in the following table.

Summary of the Basket Stresses due to Seismic Load

(2g Axial + 2g Transverse + 2g Vertical)

Component	Stress Classification	Stress (ksi)	Reference Figure
Basket	P_m	1.46	K.3.6-16
	$P_m + P_b$	5.62	K.3.6-17
Rail	P_m	1.76	K.3.6-18
	$P_m + P_b$	10.6	K.3.6-19
Canister	P_m	4.07	K.3.6-20
	$P_m + P_b$	12.13	K.3.6-21

C. Shear Stress in Basket Rail Stud due to Seismic Load

Discussion

The basket will be subjected to accelerations of 0.37g in the axial direction, 0.37g in the transverse direction, and 0.17g in the vertical direction during a seismic event. During the seismic event the inertial load of the basket and fuel assemblies in the axial direction will produce shear stresses in the basket rail stud welds. This stress is computed below.

Analysis

The minimum axial inertial load that causes the basket and fuel assemblies to slide, F_{slide}, is equal to the weight of the basket and fuel assemblies at 0.83g (1g – 0.17g) multiplied by the coefficient of friction.

F_{slide} = 0.58 × (1g – 0.17g)×[43,005 lb. (fuel assembly weight) + 22,918 lb. (basket weight)] = 31,735 lb.

The maximum axial inertial load generated by the basket and fuel assemblies during a seismic event, F, is,

F = 0.37g×[43,005 lb. (fuel assembly weight) + 22,918 lb. (basket weight)] = 24,392 lb.

Since the maximum inertial load generated by the basket and fuel assemblies is less than the minimum inertial load required to cause the basket to slide inside the canister, the basket and fuel assemblies will not slide during a seismic event. Consequently the maximum axial inertial load applied to the rail stud welds is the maximum axial inertial load generated by the basket and fuel assemblies, F.

Assuming that only the studs in the bottom three rails (8 ×7 = 56 studs) take the axial inertial load, the stress area in the rail stud welds, A, is

$$A = (\pi/4)\times(0.5^2 - 0.30^2) \times 56 = 7.037 \text{ in.}^2$$

Therefore, the shear stress generated in the stud welds, τ, is

$$\tau = F / A = 24{,}392 / 7.037 = 3{,}466 \text{ psi.} = 3.47 \text{ ksi}$$

D. Modal Analysis of the Basket

The natural frequencies of the NUHOMS®-61BT basket in the horizontal orientation are determined by performing a modal analysis.

The finite element model described in section K.3.6.1.3.1 is used to perform the modal analysis. The ANSYS computer program is used for the analysis. Weight densities are changed to mass densities ($\rho_m = \rho_w /386.4$). The fuel and poison plate weight are applied to the basket panels by increasing their density. Since only lateral modes of vibration are significant, master degree-of-freedoms are applied in the Y-direction only. Figure K.3.6-22 shows the ANSYS finite element model and locations of master degree of freedoms.

Modes and Frequencies From ANSYS Analysis

The first 4 mode frequencies resulting from the ANSYS modal analysis are tabulated below.

Mode	Frequency (Hz.)
1	125.53
2	139.95
3	142.11
4	142.40

The first three (3) mode shapes modal analysis are plotted on Figures K.3.6-23, K.3.6-24 and K.3.6-25.

Results From Hand Calculations

For the first mode shape of each drop, the deformed shape of the central basket panels resembles a simple-simple supported beam.

As an order of magnitude check, the frequency of the fundamental mode of vibration for the simple-simple supported beam is calculated below and compared to the frequency of the first mode of the ANSYS modal analysis results. Reference 3.12, page 369, case 6,"Single span, end supported, uniform load W", lists the following equation for the fundamental frequency:

$$f = 3.55 / (5WL^3/384EI)^{1/2}$$

Where:

$W = 705 \times 3/164 = 12.896$ lbs.
$L = 6.22$ in.
$E = 25.8 \times 10^6$ psi
$I = 2(3.0 \times 0.12^3/12) = 0.000864$ in.^{4}

Substituting the values given above,

$$f = 3.55 / (5 \times 12.896 \times 6.22^3/384 \times 25.8 \times 10^6 \times 0.000864)^{1/2}$$

$$f = 84 \text{ Hz}$$

This value is somewhat lower than that given by ANSYS for the basket. The actual support conditions for the basket are somewhere in between simple-simple and fixed-fixed supports. A fixed-fixed beam's fundamental frequency is approximately double (2.28) that of a simple-simple supported beam. Therefore, we should expect the ANSYS solution to be somewhere between these values.

Conclusion

Based on the results of modal analysis, it is seen that the lowest natural frequency of the basket is much higher than the threshold frequency of 33 Hz., required for satisfying the rigidity condition. It is also judged that the lowest frequency for other orientations will also be higher than 33 Hz.

E. Summary of Basket Assembly Stress Analysis due to Operation / Storage Loads

The following table summarizes the basket stress analysis results and compares them with the code allowable stresses. The maximum calculated temperature of the basket assembly during storage conditions is less than 550°F (except the blocked vent condition). For conservatism, allowables are taken at a temperature of 650° F. Level A allowables are conservatively used for Level C stresses.

Summary of Basket Structural Analysis due to Operation/Storage Load Conditions

Loading	Component	Service Level	Stress Classification	Loads	Calculated Stress (ksi)	Allowable Stress (ksi)
Horizontal Dead Weight	Basket, Rails, Canister	A	P_m	1g Down	Enveloped by Seismic Loading	
		A	$P_m + P_b$	1g Down		
Horizontal Dead Weight	Basket	A	$P_m + P_b + Q$	Conservatively using 2g Axial + 2g Vert. + 2g Trans.	17.69	48.6
	Rail	A	$P_m + P_b + Q$		11.51	48.6
	Plate Insert	D	Shear	Blocked Vent	0.06	26.38*
Seismic	Basket	C	P_m	2g Axial + 2g Vertical + 2g Transverse	1.46	16.2
		C	$P_m + P_b$		5.62	24.3
	Rails	C	P_m		1.76	16.2
		C	$P_m + P_b$		10.60	24.3
	Canister	C	P_m		4.07	16.2
		C	$P_m + P_b$		12.13	24.3
	Rail Stud	C	Shear	0.37g Axial	3.47	26.63

* Allowable based on 800°F temperature (Vent Block)

K.3.6.1.4 DSC Support Structure Analysis

The DSC support structure is shown in Figures 4.2-6 and 4.2-7 of the CSAR. The DSC support rails are supported vertically and horizontally by three moment resisting braced frames anchored to the HSM floor and side wall. The DSC support structure design uses bolted and welded connection details. Normal operating condition loads on the DSC support structure are:

- DSC Dead weight
- DSC Support Structure Dead Weight
- DSC Operational Handling Loads.

The resulting friction loading which develops between the sliding surfaces of the DSC shell and the DSC support rails is transferred axially by the support rails to the HSM front wall.

The various components of the DSC support structure are subjected to normal operating loads including dead weight, thermal, and operational handling loads and the analysis for the NUHOMS® 52B DSC is presented in Section 8.1.1.4 of the CSAR. The weight of the NUHOMS®-61BT DSC is approximately 11% greater than the NUHOMS® 52B DSC. The effect of this increased weight are evaluated by scaling the NUHOMS® 52B governing load case stress ratios that are affected by the DSC weight increase. The results of this analysis are presented in Table K.3.7-2 which shows that all the limiting DSC Support Structure components are acceptable.

K.3.6.1.5 HSM Design Analysis

The structural analysis of an individual module provides a conservative methodology for evaluating the response of the HSM structural elements under various static and dynamic loads for any HSM array configured in accordance with Section 4.1.1 of the CSAR. The HSM loads analysis for the NUHOMS® 52B system is presented in Section 8.1.1.5 of the CSAR. This analysis is applicable to NUHOMS®-61BT system with two differences which are discussed below:

A. HSM Dead Load and Live Load Analyses

The weight of a HSM loaded with the NUHOMS®-61BT DSC is approximately 2.5% greater than a module loaded with the NUHOMS® 52B DSC. The weight of the NUHOMS-61BT DSC is approximately 11% greater than the NUHOMS® 52B DSC. This comparison is presented in Section K.3.7.10.5. The effects of this 11% increased payload weight are evaluated by scaling the governing load case stress ratios that are affected by the DSC weight increase to ensure that the ratios are less than 1.0. The results of this analysis are presented in Table K.3.7-2, which shows that all the limiting concrete components are acceptable.

B. HSM Thermal Loads Analysis

The thermal loads for the NUHOMS® HSM as described in section 8.1.1.5.C of the CSAR are based on a payload of 24 kilowatts (24P DSC) and thus envelope the thermal loads for a NUHOMS®-61BT DSC which has a total payload of 18.3 kilowatts.

K.3.6.1.6 HSM Door Analyses

No change

K.3.6.1.7 HSM Heat Shield Analysis

No change

K.3.6.1.8 HSM Axial Retainer for DSC

The structural evaluation for the HSM axial retainer is addressed in Section K.3.7.3 paragraph C.

K.3.6.1.9 On-Site Transfer Cask Analysis

The on-site transfer cask is evaluated for normal operating condition loads including:

1. Dead Weight Load
2. Thermal Loads
3. Handling Loads
4. Live Loads.

The NUHOMS® OS 197 transfer cask is shown in Figures 1.3-6 and on the licensing drawings contained in Appendix E of the CSAR. Section 8.1.1.9 of the CSAR provides the evaluation of the transfer cask for the normal operating loads when handling the NUHOMS® 52B DSC. Thermal loads and live loads for the OS 197 transfer cask with the NUHOMS®-61BT DSC are equivalent to or less than those for the cask with the NUHOMS® 52B DSC.

Section K.3.7.10.3 provides the evaluation of the OS 197 transfer cask when handling the heavier payload due to NUHOMS®-61BT DSC.

K.3.6.2 Off-Normal Load Structural Analysis

Table K.3.6-2 shows the off-normal operating loads for which the NUHOMS® safety-related components are designed. This section describes the design basis off-normal events for the NUHOMS® system and presents analyses which demonstrate the adequacy of the design safety features of a NUHOMS® system.

For an operating NUHOMS® system, off-normal events could occur during fuel loading, cask handling, trailer towing, canister transfer and other operational events. Two off-normal events are defined which bound the range of off-normal conditions. The limiting off-normal events are defined as a jammed DSC during loading or unloading from the HSM and the extreme ambient temperatures of -40°F (winter) and +125°F (summer). These events envelope the range of expected off-normal structural loads and temperatures acting on the DSC, transfer cask, and HSM. These off-normal events are described in Section 8.1.2 of the CSAR.

K.3.6.2.1 Jammed DSC During Transfer

The interfacing dimensions of the top end of the transfer cask and the HSM access opening sleeve are specified so that docking of the transfer cask with the HSM is not possible should gross misalignments between the transfer cask and HSM exist. Furthermore, beveled lead-ins are provided on the ends of the transfer cask, DSC, and DSC support rails to minimize the possibility of a jammed DSC during transfer. Nevertheless, it is postulated that if the transfer cask is not accurately aligned with respect to the HSM, the DSC binds or becomes jammed during transfer operations.

There is no change in the outside diameter of the NUHOMS®-61BT DSC as compared to NUHOMS 52B. In addition, the interfacing dimensions and design features of the HSM access opening, DSC Support Structure and the OS 197 transfer as described in CSAR Section 8.1.2 remain unchanged. The insertion and extraction forces applied on the NUHOMS 61B during loading and unloading operations are the same as those specified for the NUHOMS 52B system. Hence the analysis for a jammed canister as described in CSAR Section 8.1.2 for NUHOMS® 52B remains applicable to NUHOMS®-61BT system.

K.3.6.2.2 Off-Normal Thermal Loads Analysis

As described in CSAR Section 8.1.2, the NUHOMS® system is designed for use at all reactor sites within the continental United States. Therefore, off-normal ambient temperatures of -40°F (extreme winter) and 125°F (extreme summer) are conservatively chosen. In addition, even though these extreme temperatures would likely occur for a short period of time, it is conservatively assumed that these temperatures occur for a sufficient duration to produce steady state temperature distributions in each of the affected NUHOMS® components. Each licensee should verify that this range of ambient temperatures envelopes the design basis ambient temperatures for the ISFSI site. The NUHOMS® system components affected by the postulated extreme ambient temperatures are the transfer cask and DSC during transfer from the plant's fuel/reactor building to the ISFSI site, and the HSM during storage of a DSC.

Section K.4.0 provides the off-normal thermal analyses for storage and transfer mode for the NUHOMS®-61BT DSC. The resulting stress intensities for the NUHOMS®-61BT are acceptable.

Table K.3.6-1
NUHOMS® Normal Operating Loading Identification

Load Type	Affected Component				
	DSC Shell Assembly	DSC Basket	DSC Support Structure	Reinforced Concrete HSM	On-site Transfer Cask
Dead Weight	X	X	X	X	X
Internal/External Pressure	X				
Normal Thermal	X	X	X	X	X
Normal Handling	X	X	X	X	X
Live Loads				X	X

Table K.3.6-2
NUHOMS® Off-Normal Operating Loading Identification

Load Type	Affected Component				
	DSC Shell Assembly	**DSC Basket**	**DSC Support Structure**	**Reinforced Concrete HSM**	**On-site Transfer Cask**
Dead Weight	X	X	X	X	X
Internal/External Pressure	X				
Off-Normal Thermal	X	X	X	X	X
Off-Normal Handling	X	X	X	X	X

Table K.3.6-3
Mechanical Properties of Materials

Material	Temperature (°F)	Stress Properties[1] (ksi)			Elastic Modulus[1] (x1.0E3 ksi) (E)	Average Coefficient of Thermal Expansion[1] ($x10^{-6}$ in./in.-°F)
		Stress Intensity (S_m)	Yield Strength (S_y)	Ultimate Strength (S_u)		
Stainless Steel ASME SA240 Type 304	-100	--	--	--	29.1	--
	-20	20.0	30.0	75.0	--	--
	70	-	--	--	28.3	--
	100	20.0	30.0	75.0	--	8.56
	200	20.0	25.0	71.0	27.6	8.9
	400	18.7	20.7	64.0	26.5	9.2
	500	17.5	19.4	63.4	25.8	9.7
	600	16.4	18.4	63.4	25.3	9.8
	700	16.0	17.6	63.4	24.8	10.0

Table K.3.6-3
Mechanical Properties of Materials

(continued)

Material	Temperature (°F)	Stress Properties(1) (ksi)			Elastic Modulus(1) (x1.0E3 ksi) (E)	Average Coefficient of Thermal Expansion(1) ($x10^{-6}$ in./in.-°F)
		Stress Intensity (S_m)	Yield Strength (S_y)	Ultimate Strength (S_u)		
Carbon(2) Steel ASME SA-36	-100	--	--	--	30.2	--
	-20	19.3	36.0	58.0	--	--
	70	--	--	--	29.5	--
	100	19.3	36.0	58.0	-	6.5
	200	19.3	33.0	58.0	28.8	6.7
	400	19.3	30.8	58.0	27.7	7.1
	500	19.3	29.3	58.0	27.3	7.3
	600	17.7	27.6	58.0	26.7	7.4
	700	17.3	25.8	58.0	25.5	7.6

(1) Steel data and thermal expansion coefficients are obtained from ASME Boiler and Pressure Vessel Code, Section II, Part D [3.2].

(2) Allowable stress values for ASTM A36 steel are based on SA-36 given in Section II, Part D of the ASME Boiler and Pressure Vessel Code.

Table K.3.6-4
Maximum NUHOMS®-61BT DSC Stresses for Normal and Off-Normal Loads

DSC Components	Stress Type	Maximum Stress Intensity(ksi)[1]			
		Dead Weight	Internal Pressure[7]	Thermal[2]	Normal Handling[4]
DSC Shell	Primary Membrane	2.76	3.07	N/A	2.76
	Membrane + Bending	3.19	8.00	N/A	3.92
	Primary + Secondary	2.90	24.22[8]	32.45	53.69[9]
Inner Top Cover Plate	Primary Membrane	0.72	1.80	N/A	2.26
	Membrane + Bending	2.12	8.58	N/A	2.56
	Primary + Secondary[5]	2.04	7.24[8]	26.61	2.57
Outer Top Cover Plate	Primary Membrane	1.17	3.75	N/A	1.17
	Membrane + Bending	1.78	14.31[8]	N/A	1.78
	Primary + Secondary[5]	1.26	10.54[8]	25.03	1.26

See End of Table for Notes.

Table K.3.6-4
Maximum NUHOMS®-61BT DSC Stresses for Normal and Off-Normal Loads

(concluded)

DSC Components	Stress Type	Maximum Stress Intensity(ksi)[1]			
		Dead Weight	Internal Pressure[7]	Thermal[2]	Normal Handling[4]
Inner Bottom Cover Plate	Primary Membrane	0.75	0.56[8]	N/A	3.41
	Membrane + Bending	0.89	1.38[8]	N/A	5.09
	Primary + Secondary	0.89	1.38[8]	27.64	37.71[9]
Outer Bottom Cover Plate	Primary Membrane	0.70	0.82[8]	N/A	4.75
	Membrane + Bending	1.18	1.50[8]	N/A	22.75
	Primary + Secondary[5]	1.11	1.10[8]	28.11	34.88[9]

(1) Values shown are maximum irrespective of location.
(2) Envelope of Normal and Off-Normal ambient temperature conditions.
(3) Not used.
(4) Maximum of deadweight, 1g axial, 60 kips pull or 80 kips push (except as noted).
(5) Per Note 2 of Table NB3217-1, the stress at the intersection between a shell and a flat head may be classified as secondary (Q) if the bending moment at the edge is not required to maintain the bending stresses in the middle of the head within acceptable limits. Thus, the primary plus secondary stresses were computed in a finite element model that assumed moment transferring connections, whereas the primary membrane plus bending stresses were computed assuming pinned connections. All thermal stresses are classified as secondary.
(6) Not used.
(7) The DSC internal structures are not affected by pressure loads.
(8) The 10 psi internal pressure results are scaled to obtain stresses for the off-normal condition 20 psi internal pressure.
(9) Results are for the combination of deadweight, 20 psi internal pressure, the 80 kip ram push load and thermal.

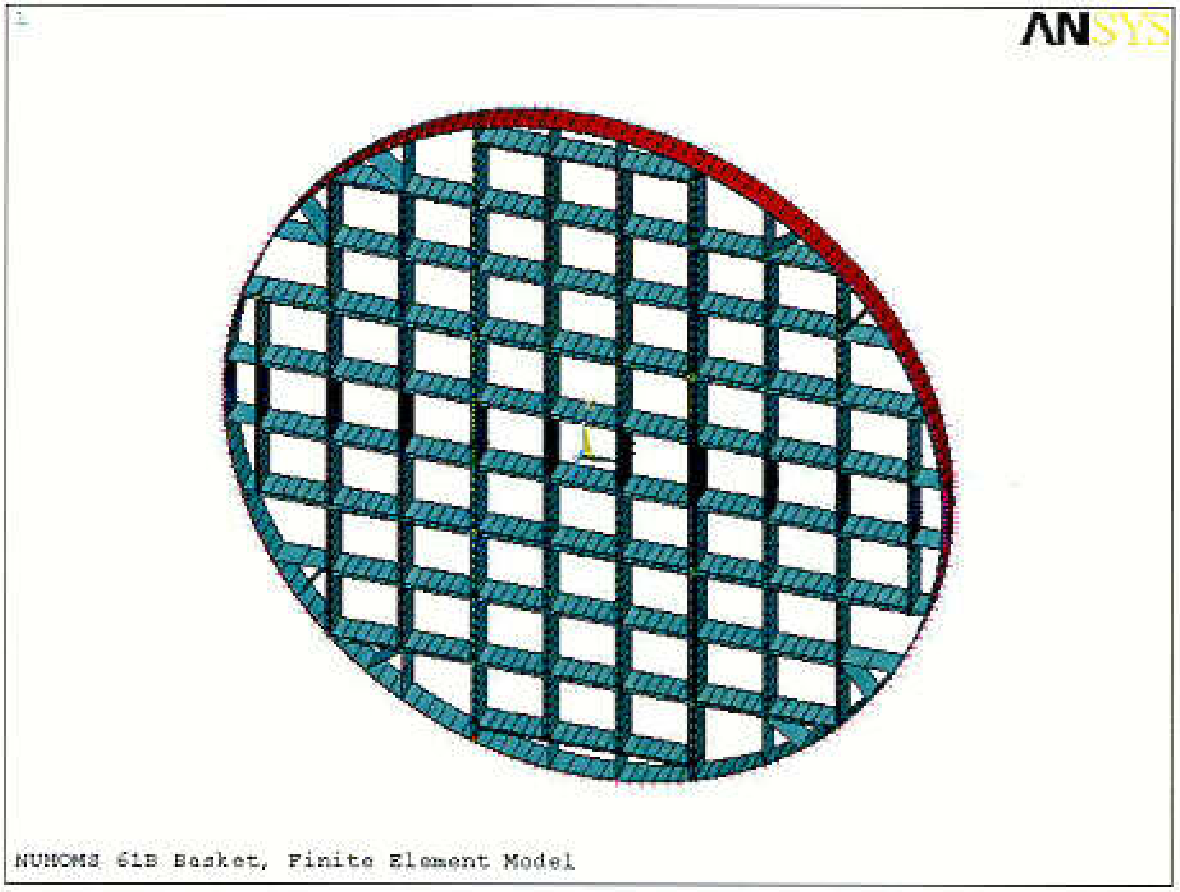


Figure K.3.6-1
Finite Element Model – Full Basket Section

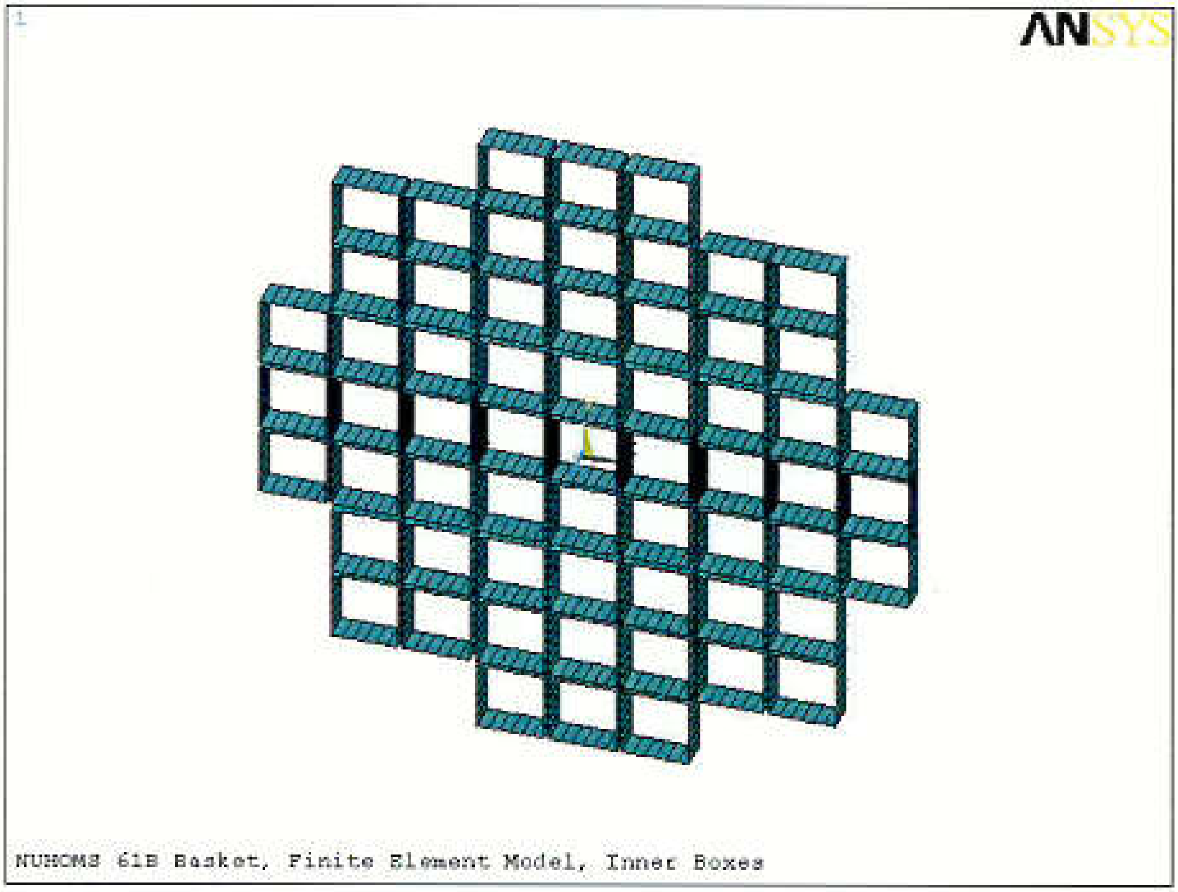


Figure K.3.6-2
Finite Element Model – Inner Boxes
(Compartment Tubes)

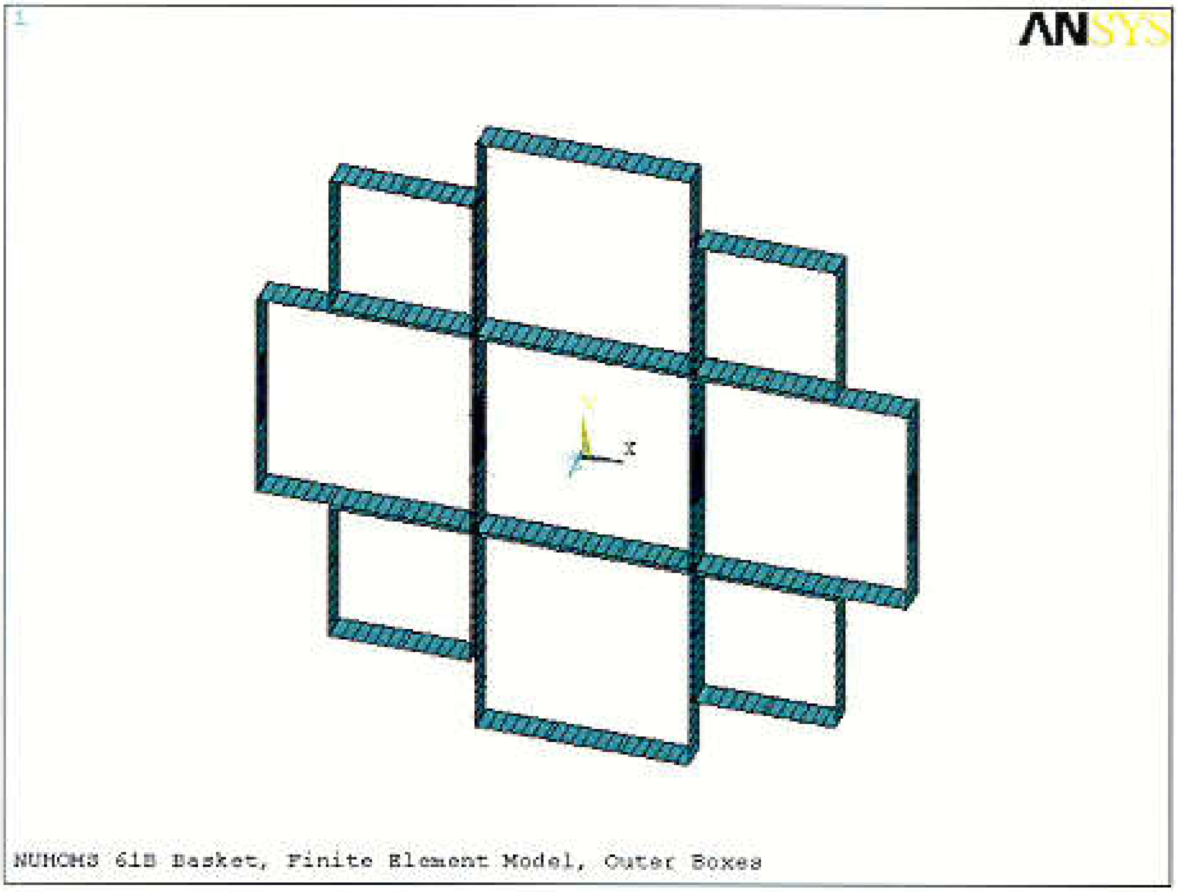


Figure K.3.6-3
Finite Element Model – Outer Boxes
(Stainless Steel Wrap)

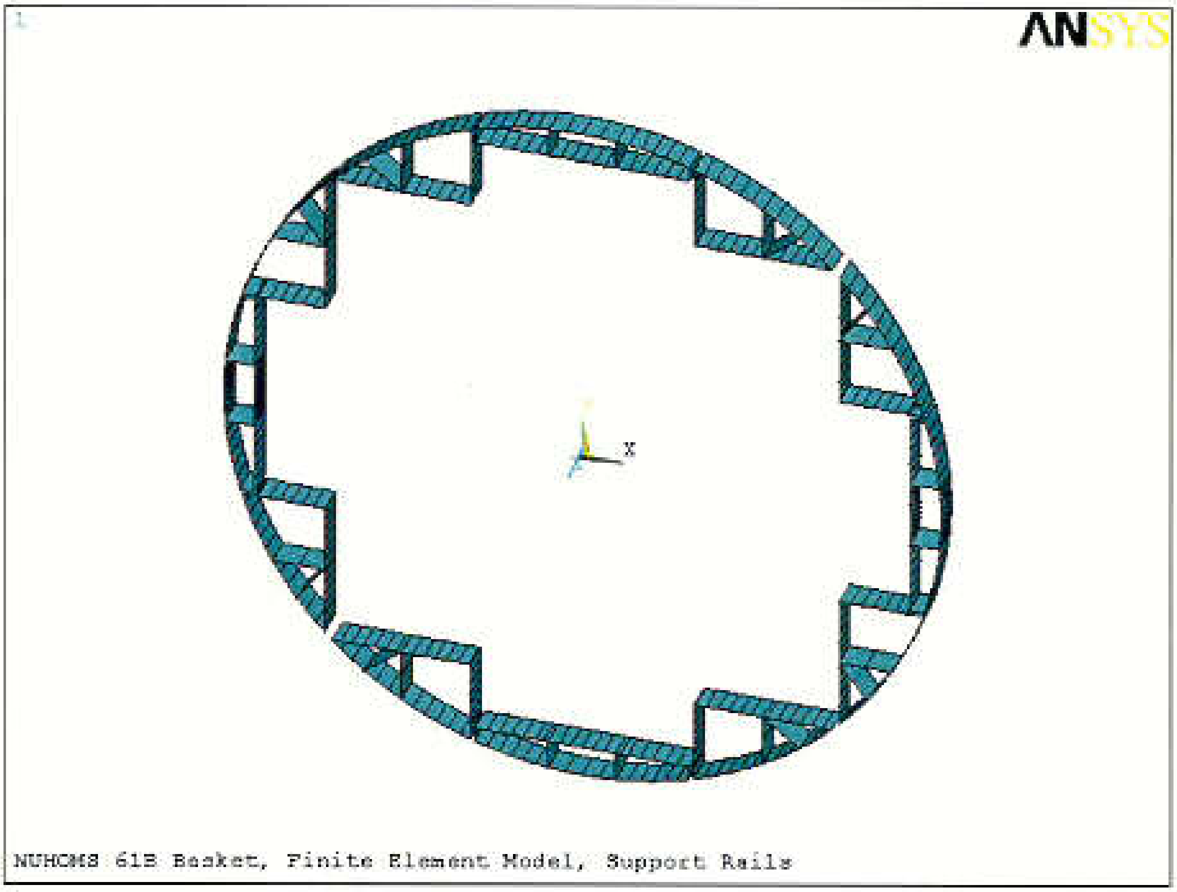


Figure K.3.6-4
Finite Element Model – Rails

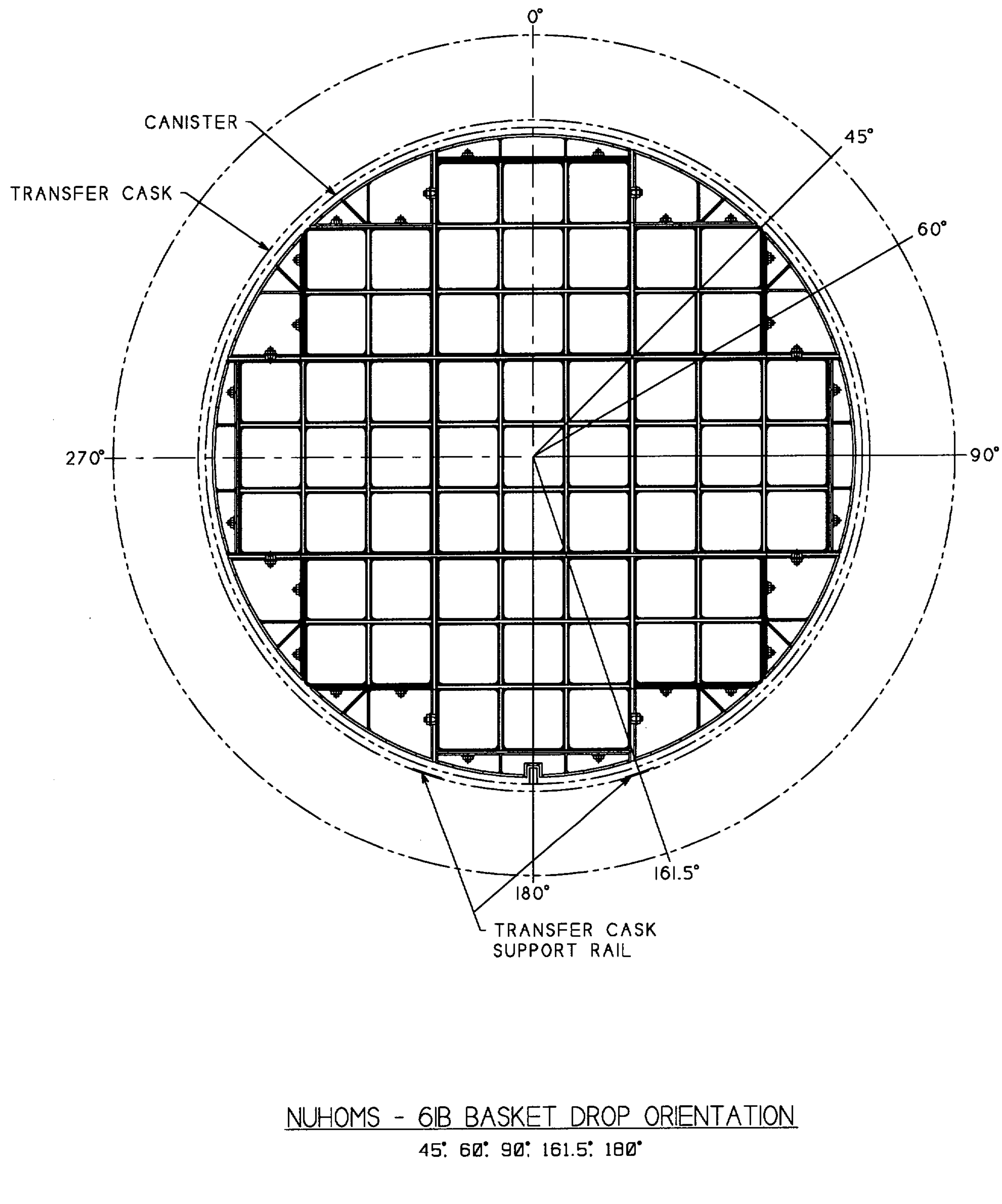


Figure K.3.6-5
NUHOMS-61B Basket Side Drop Analysis

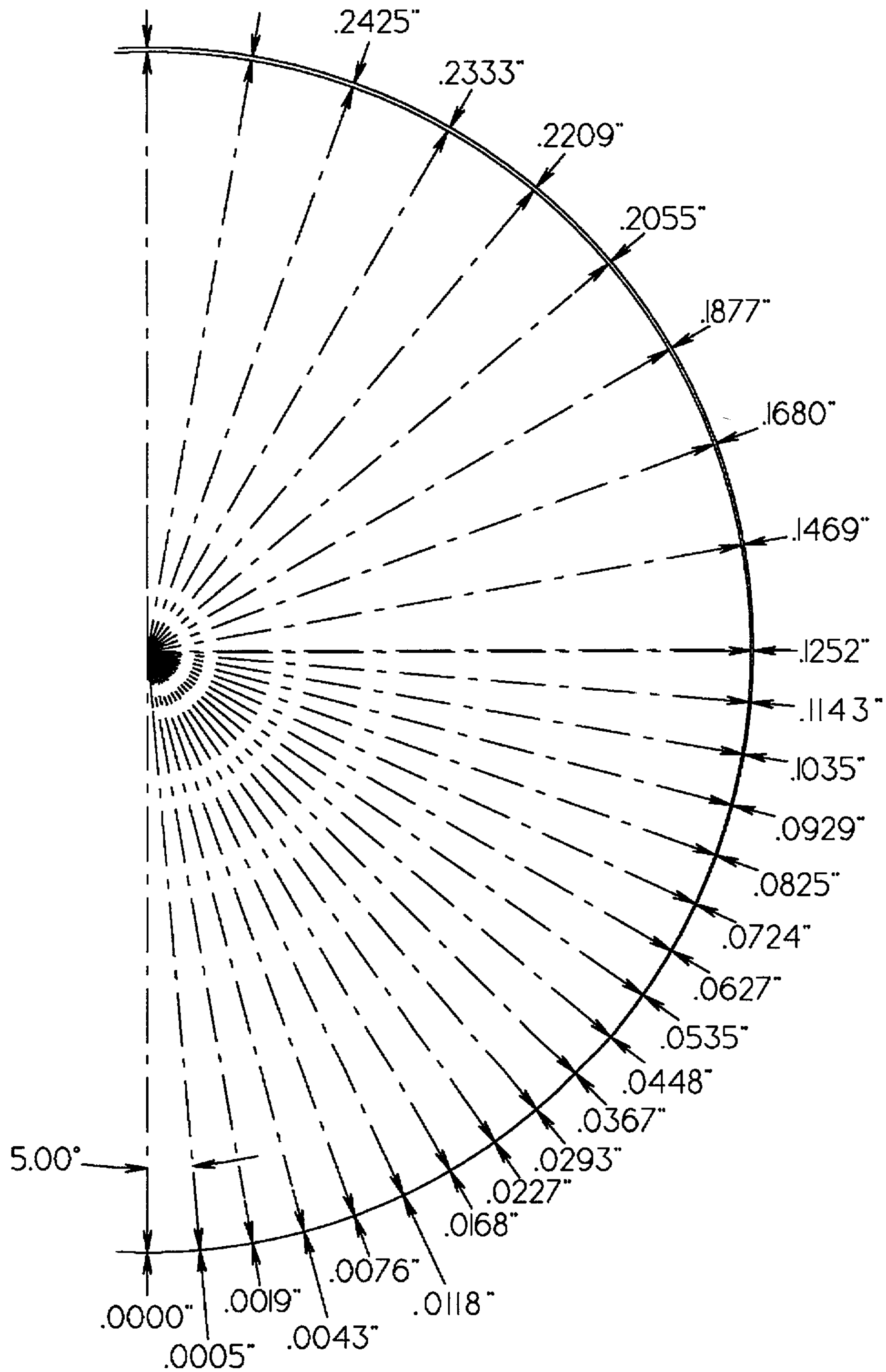


Figure K.3.6-6
Gap Sizes Between Basket Rails and Canister Inner Surfaces

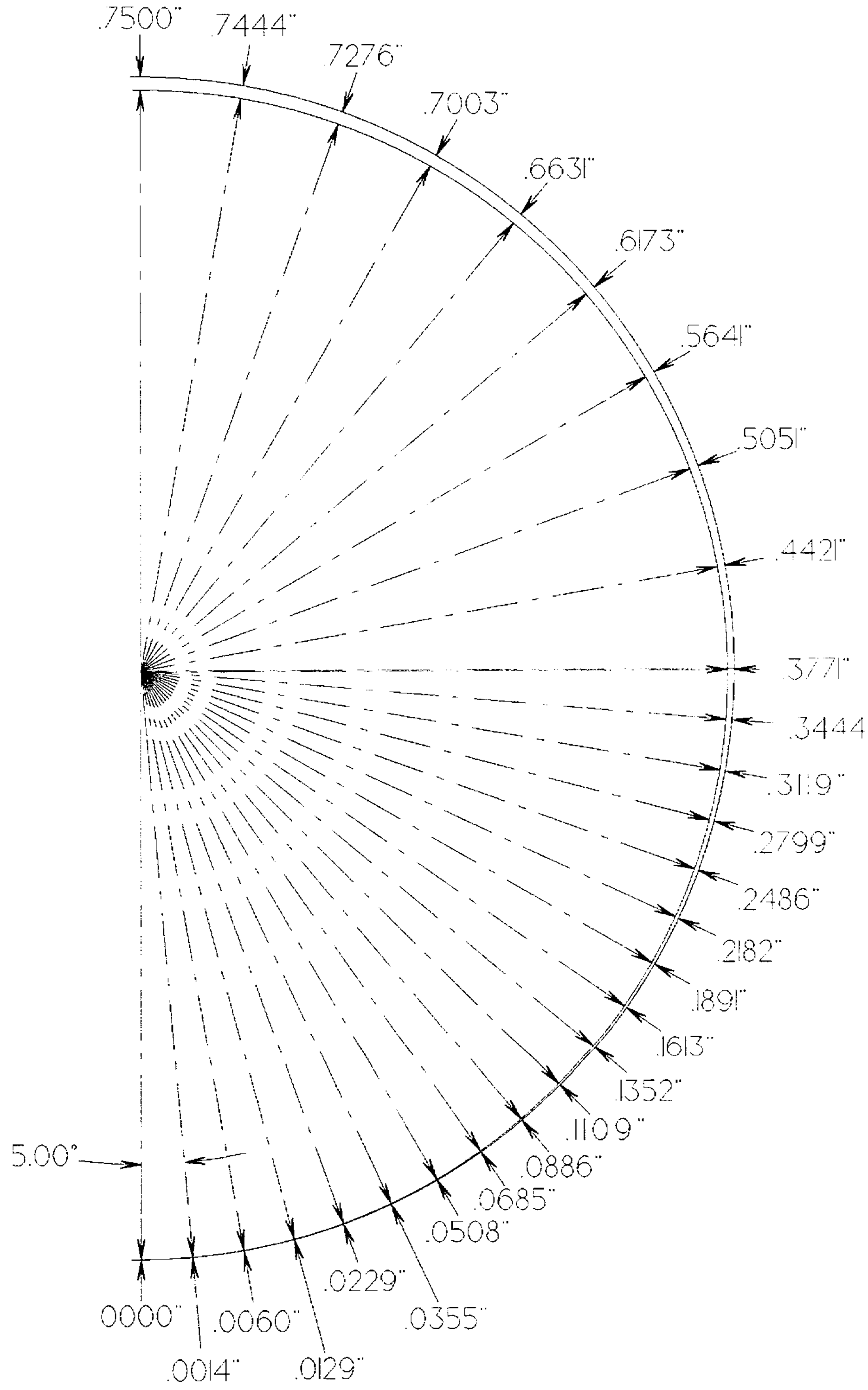


Figure K.3.6-7
Gap Sizes Between Canister Outer Surface and Cask Inner Surfaces

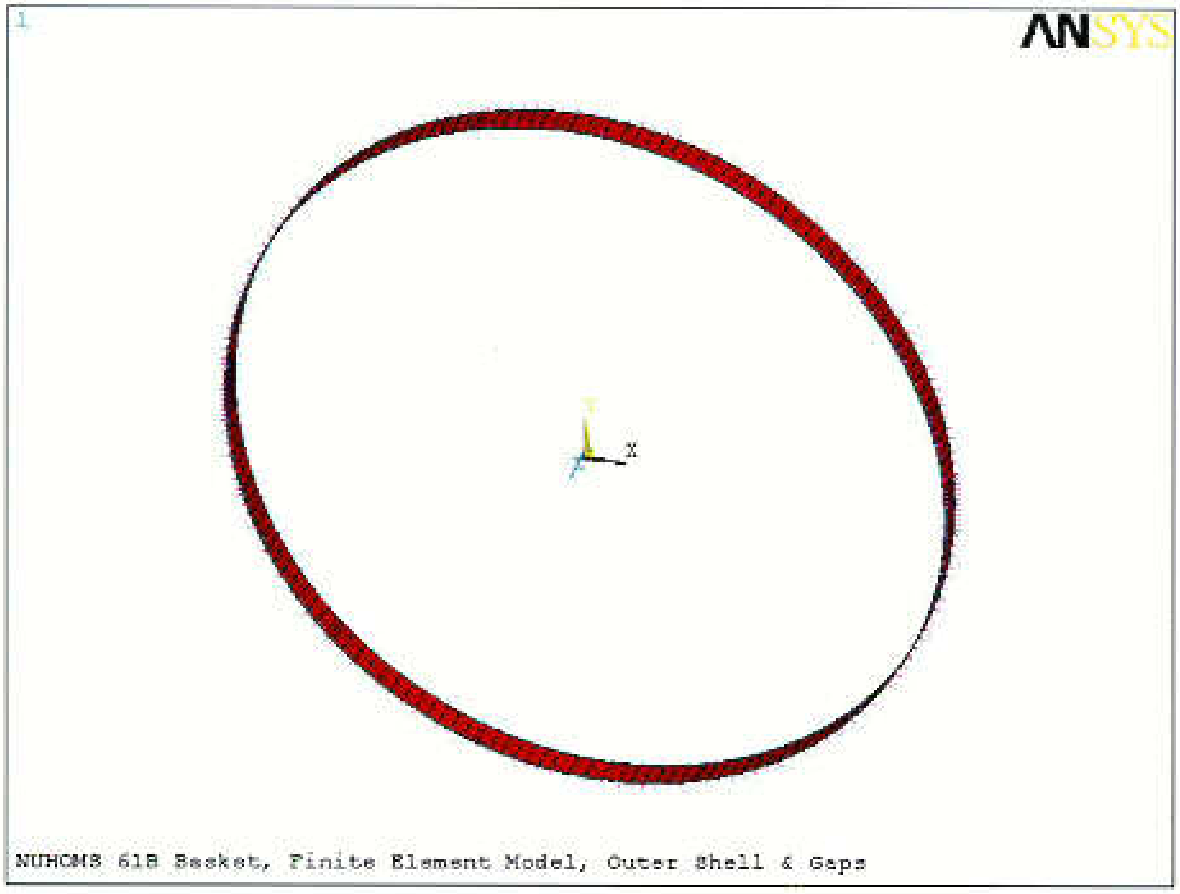


Figure K.3.6-8
Finite Element Model – Canister & Gaps

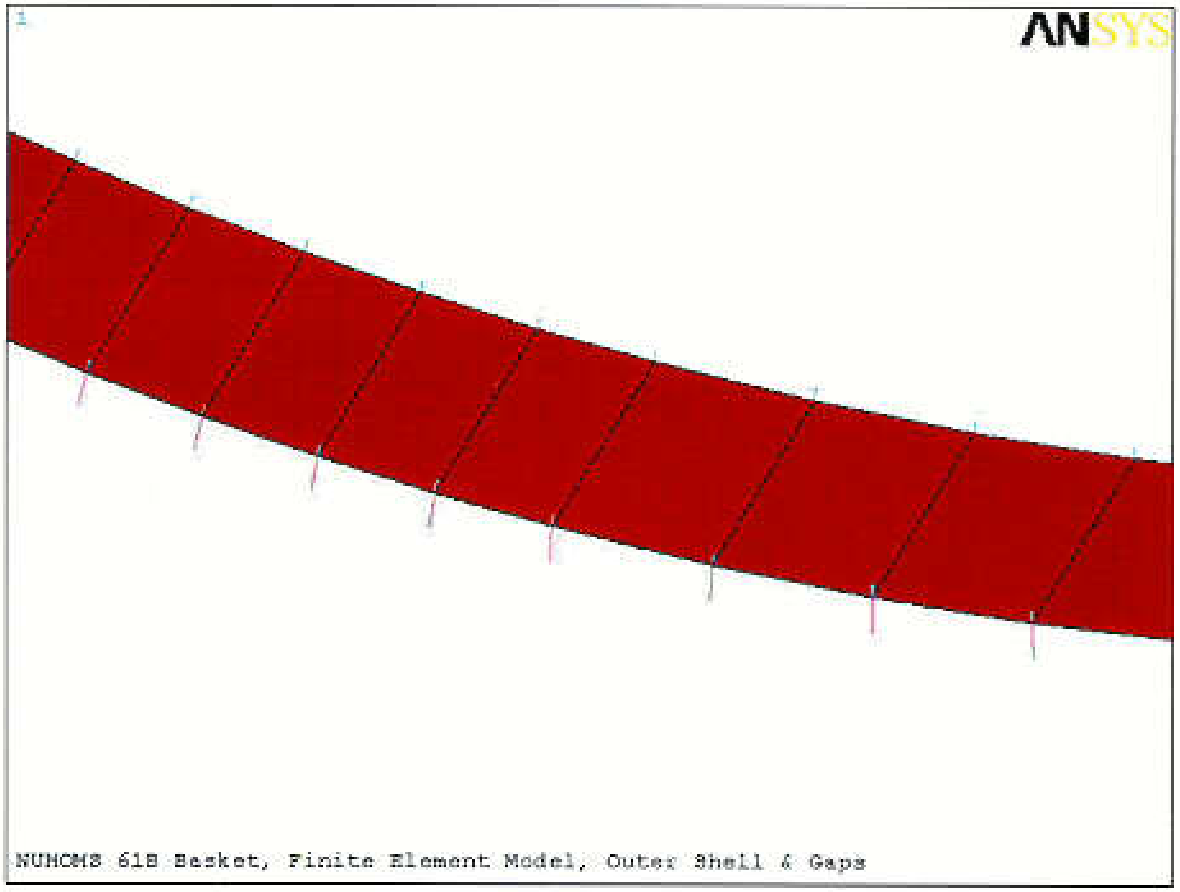


Figure K.3.6-9
Finite Element Model – Canister & Gaps, Enlarged View

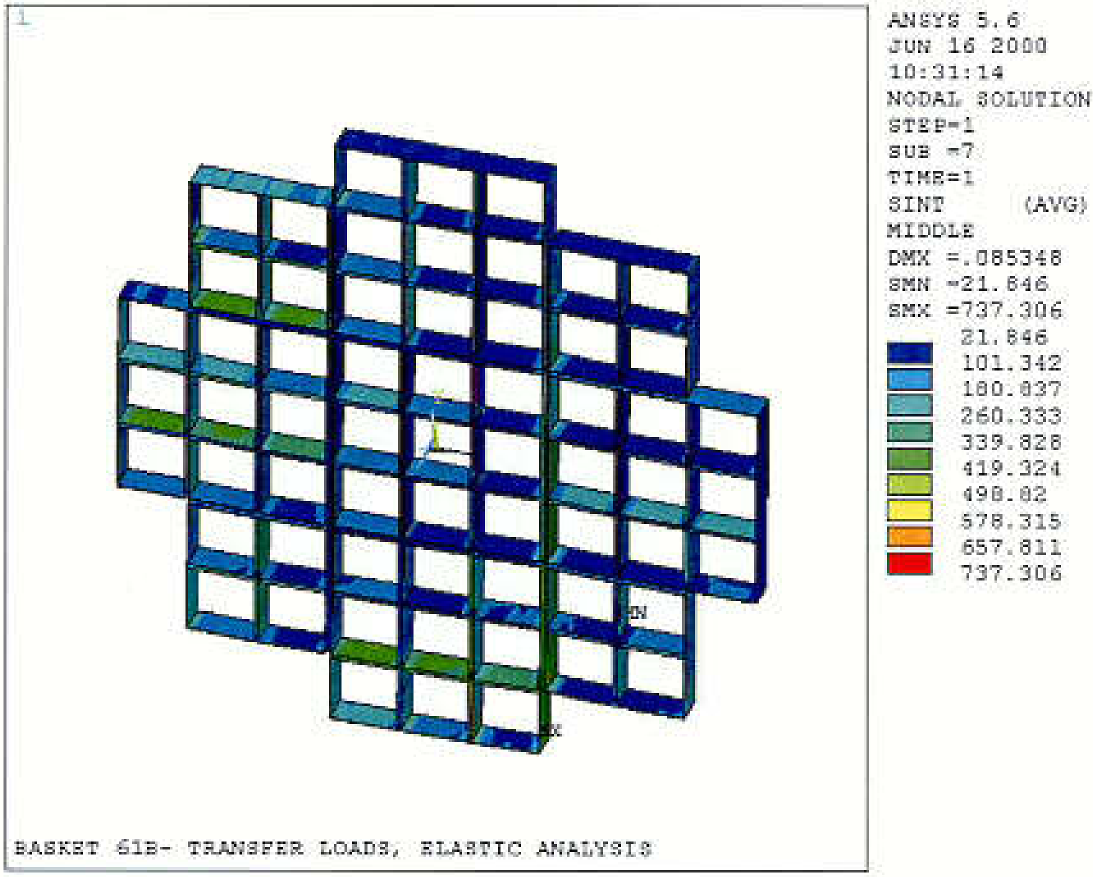


Figure K.3.6-10
Basket Membrane Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

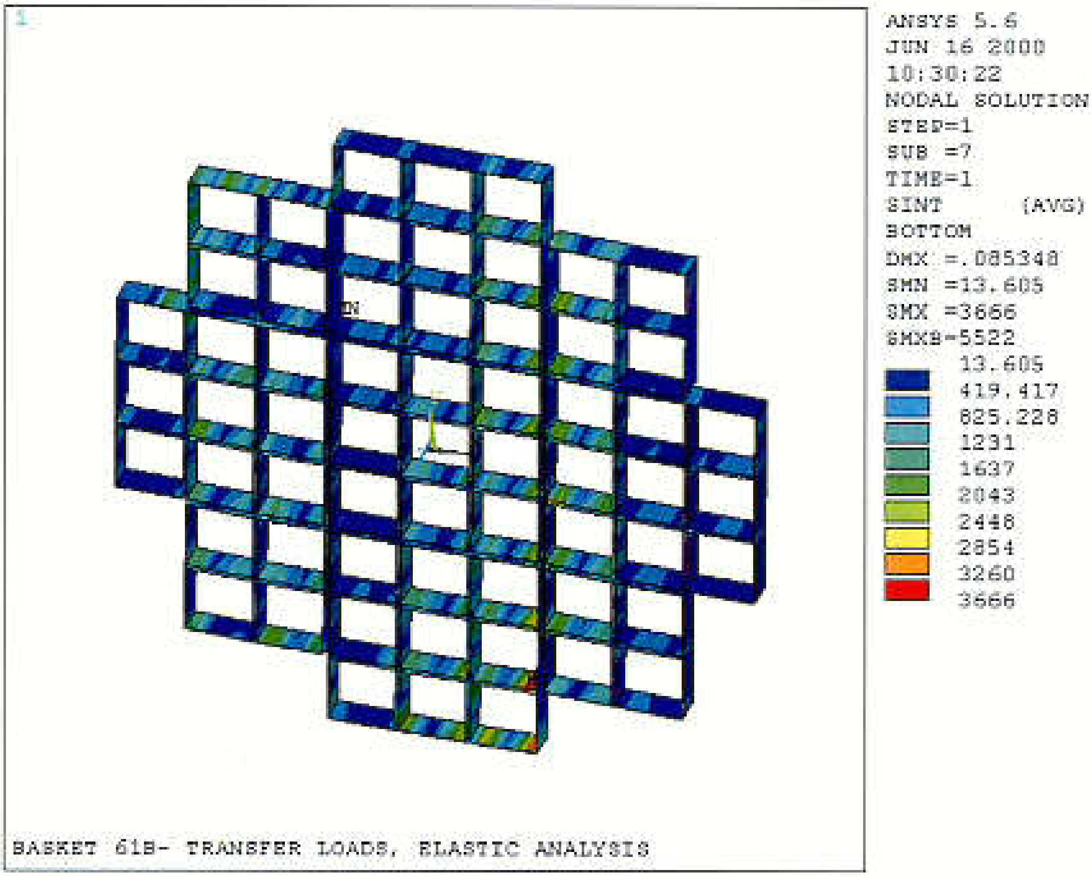


Figure K.3.6-11
Basket Membrane + Bending Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

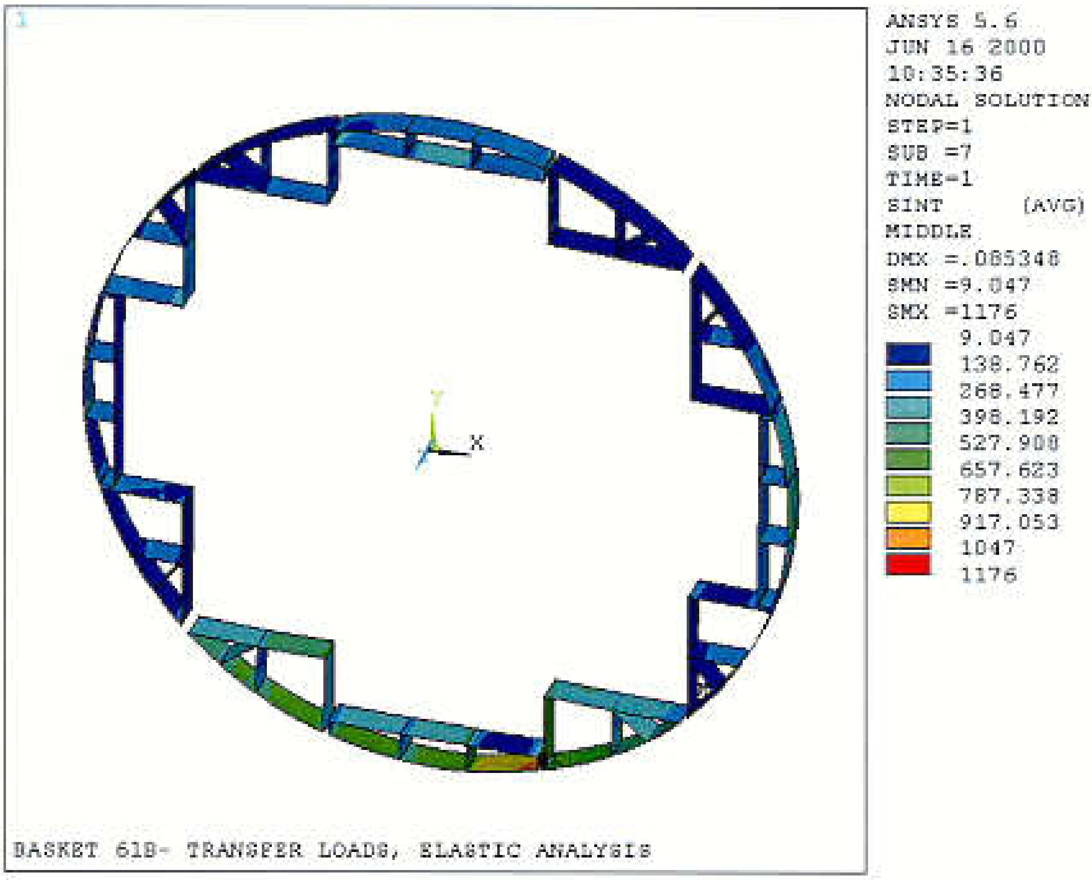


Figure K.3.6-12
Rail Membrane Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

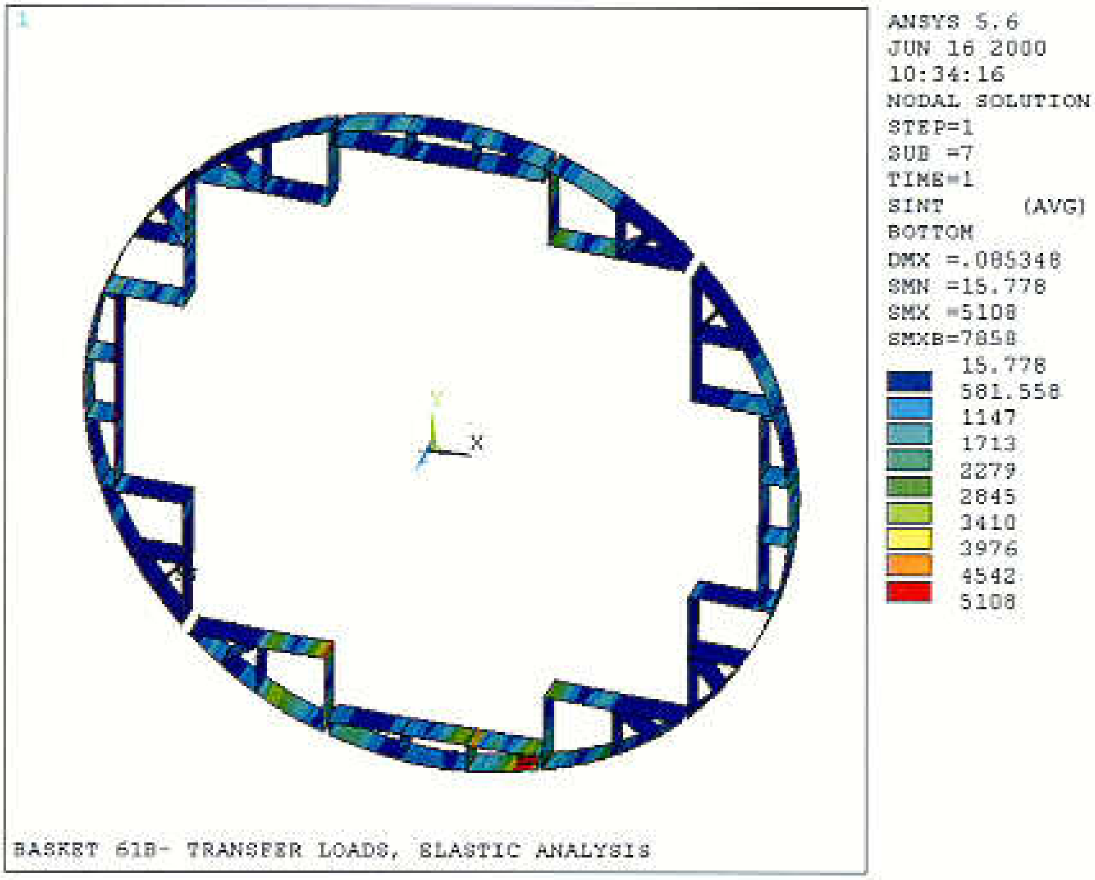


Figure K.3.6-13
Rail Membrane + Bending Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

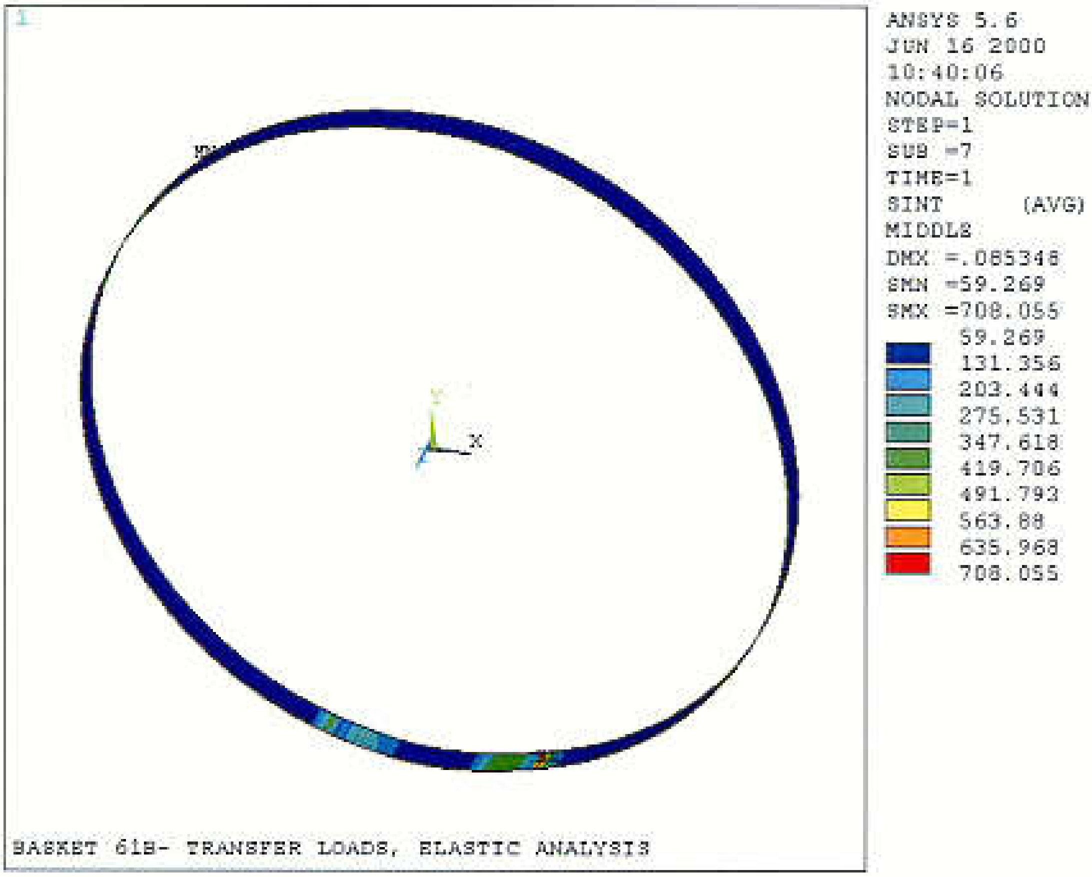


Figure K.3.6-14
Canister Shell Membrane Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

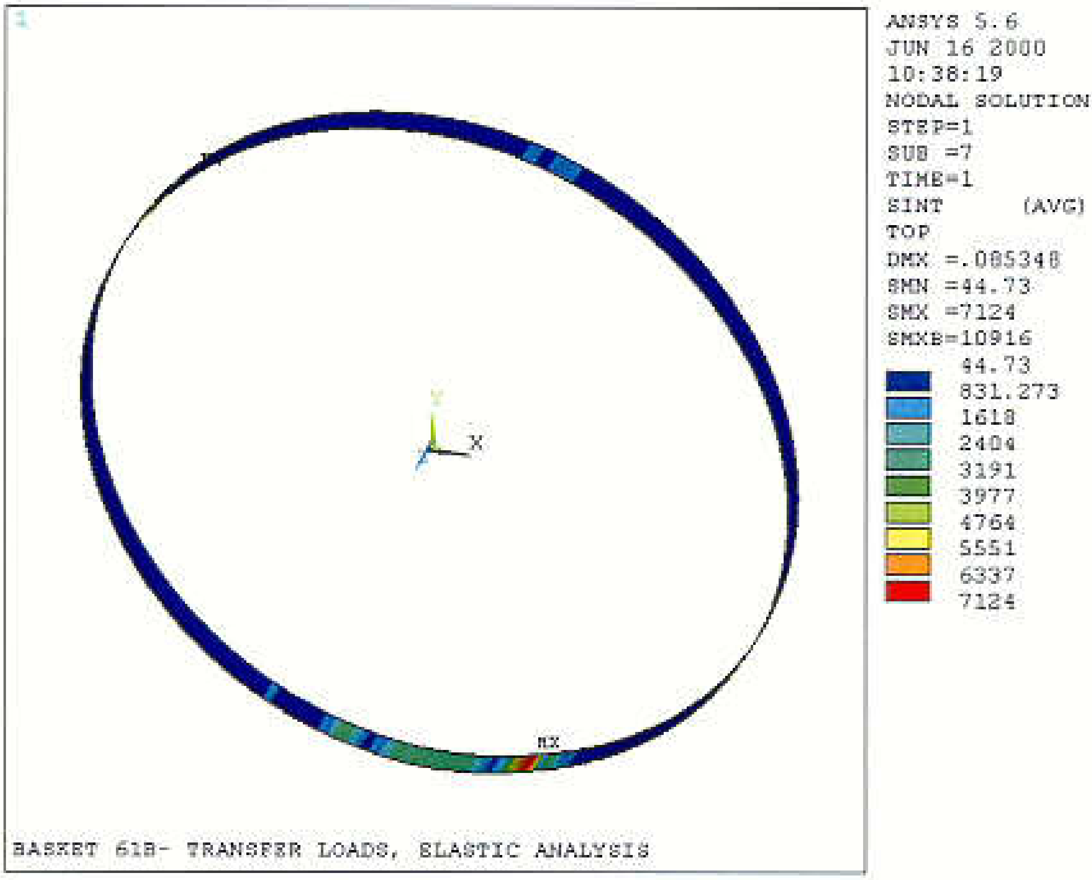


Figure K.3.6-15
Canister Shell Membrane + Bending Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

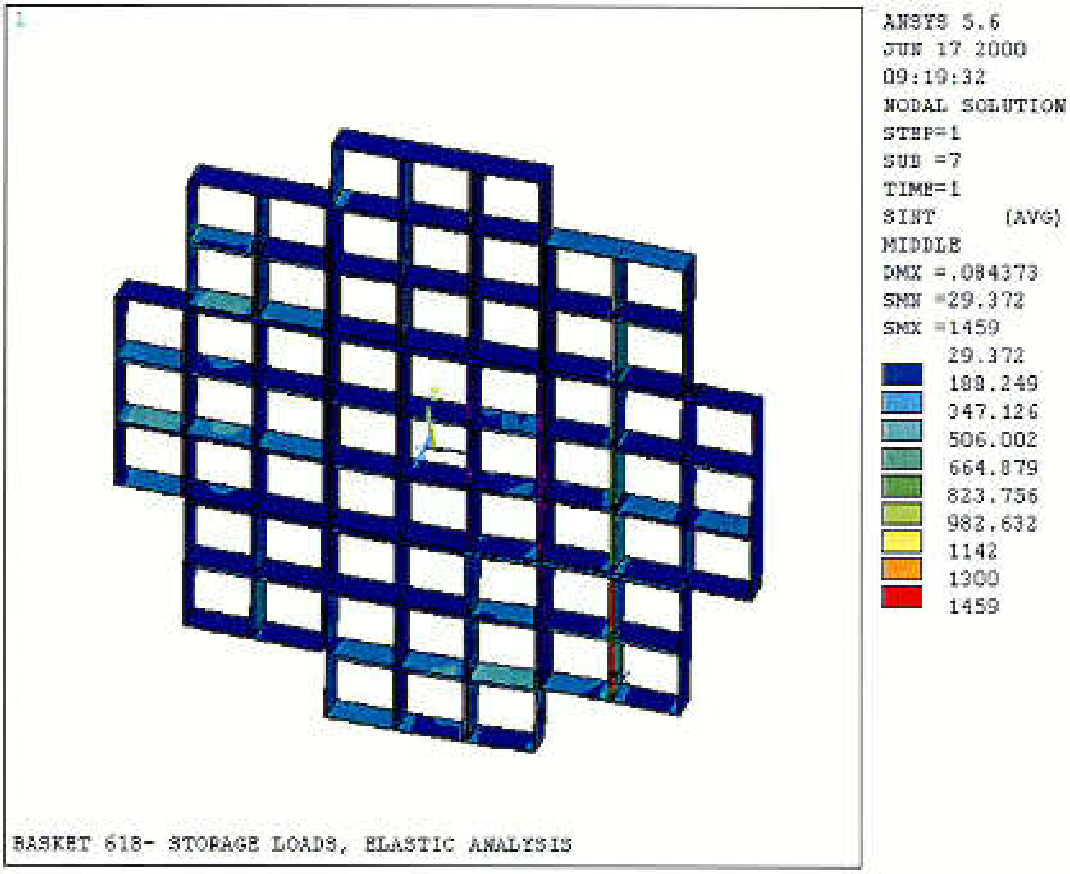


Figure K.3.6-16
Basket Membrane Stress
(2g axial + 2g transverse + 2g vertical, Operation / Storage Load)

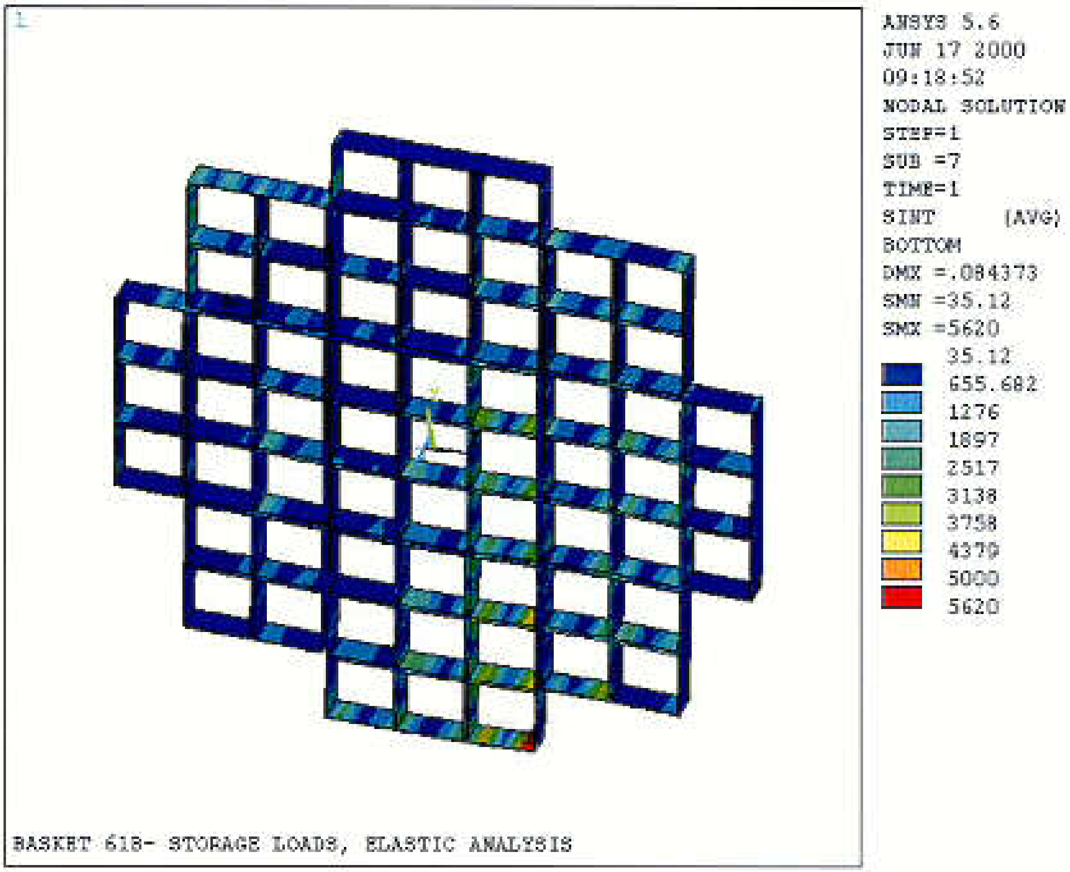


Figure K.3.6-17
Basket Membrane + Bending Stress
(2g axial + 2g transverse + 2g vertical, Operation / Storage Load)

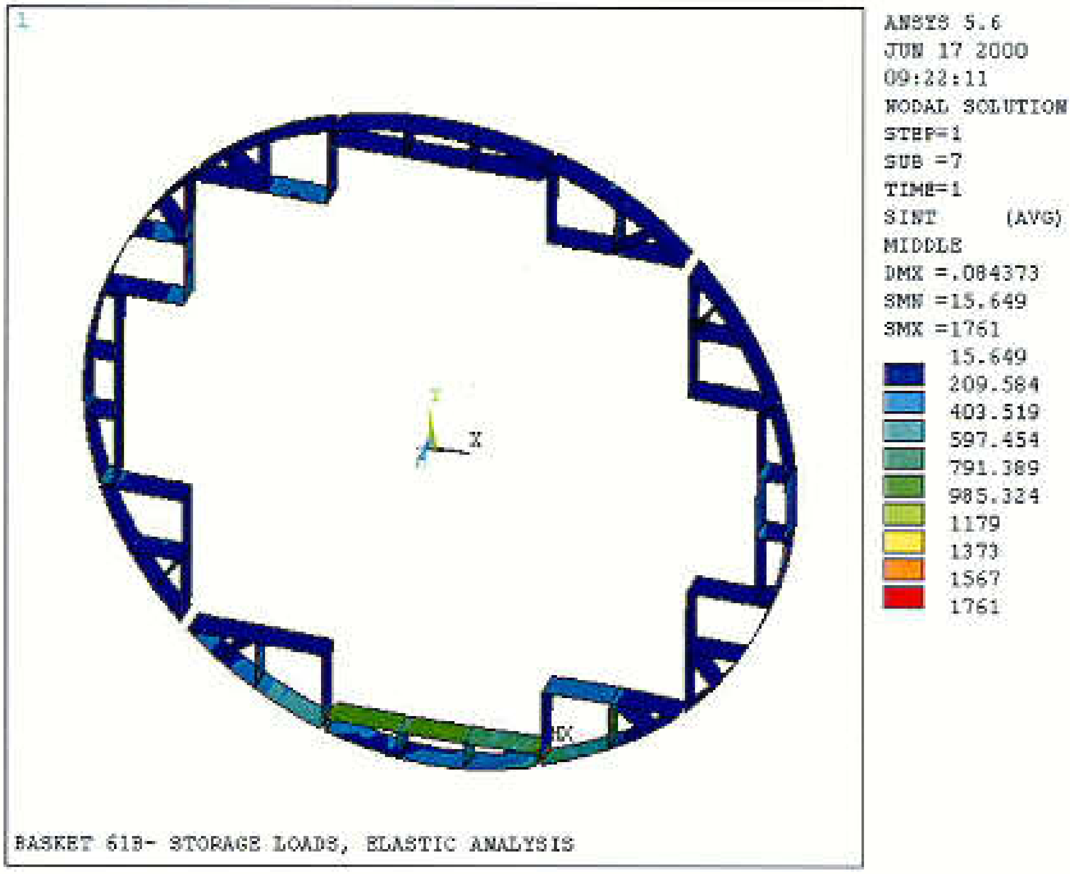


Figure K.3.6-18
Rail Membrane Stress
(2g axial + 2g transverse + 2g vertical, Operation / Storage Load)

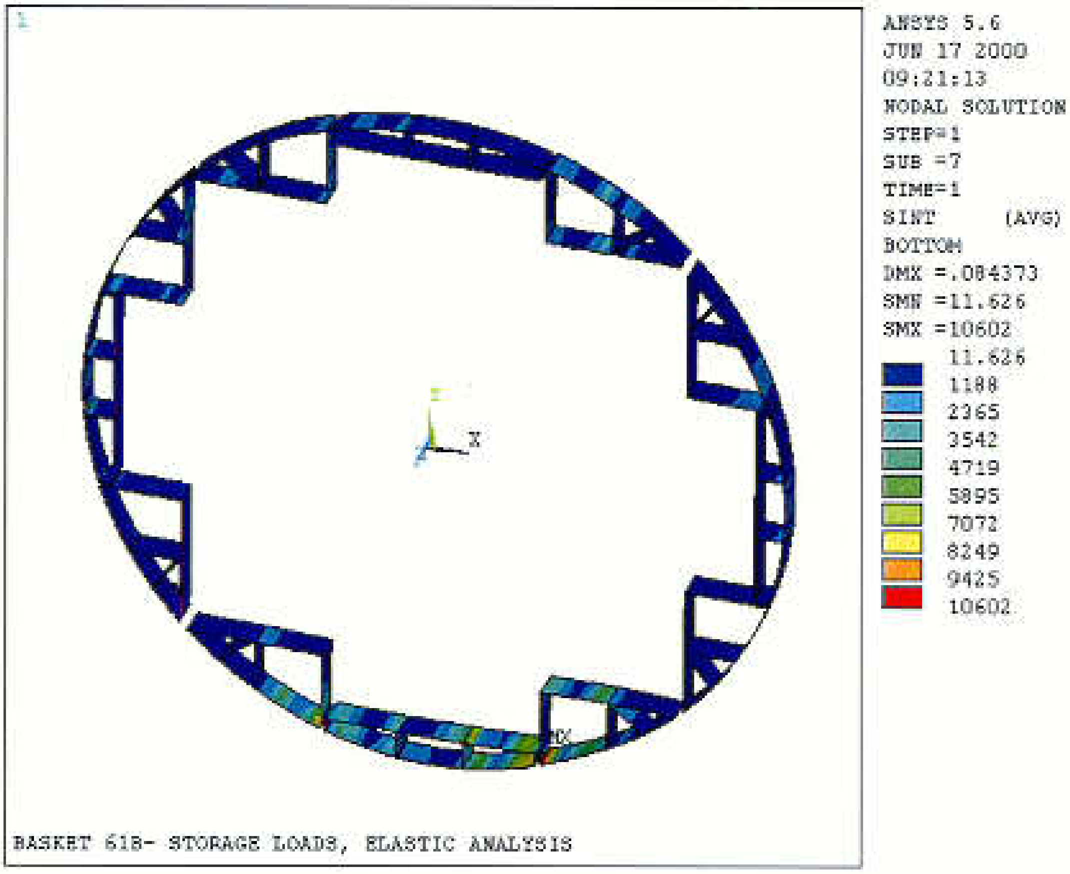


Figure K.3.6-19
Rail Membrane + Bending Stress
(2g axial + 2g transverse + 2g vertical, Operation / Storage Load)

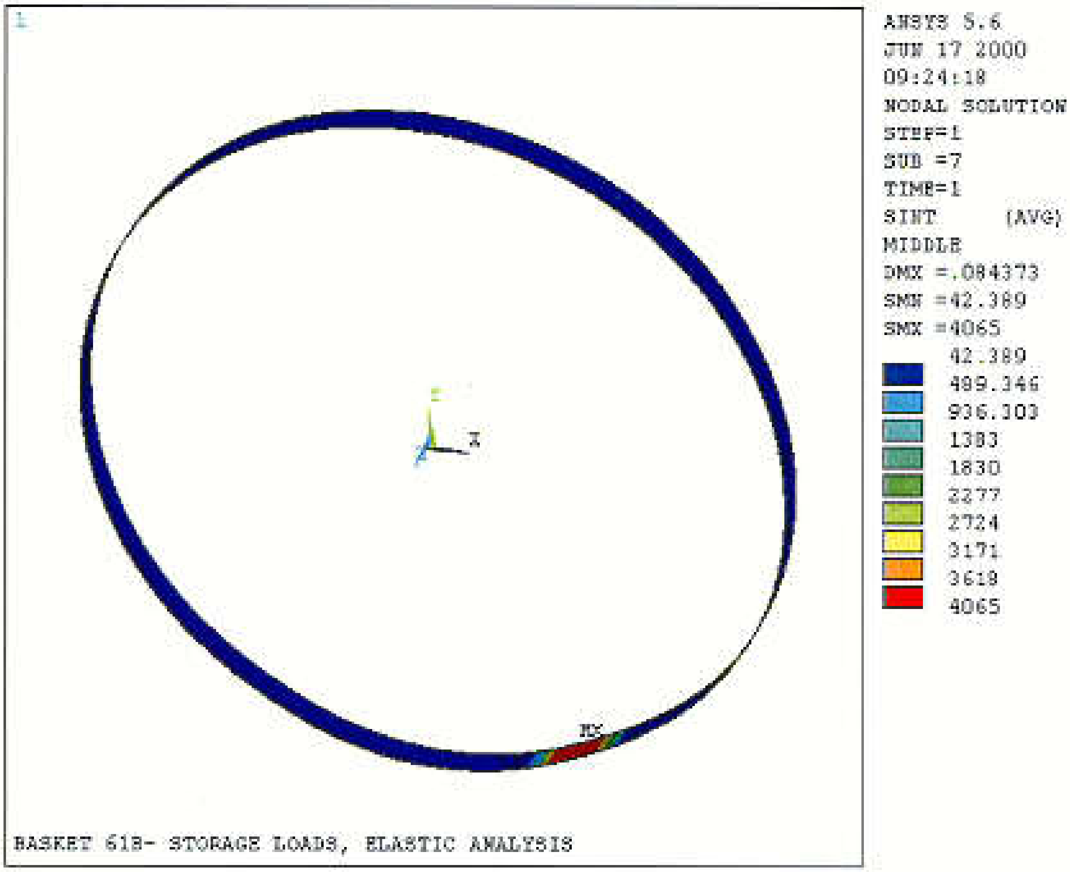


Figure K.3.6-20
Canister Shell Membrane Stress
(2g axial + 2g transverse + 2g vertical, Operation / Storage Load)

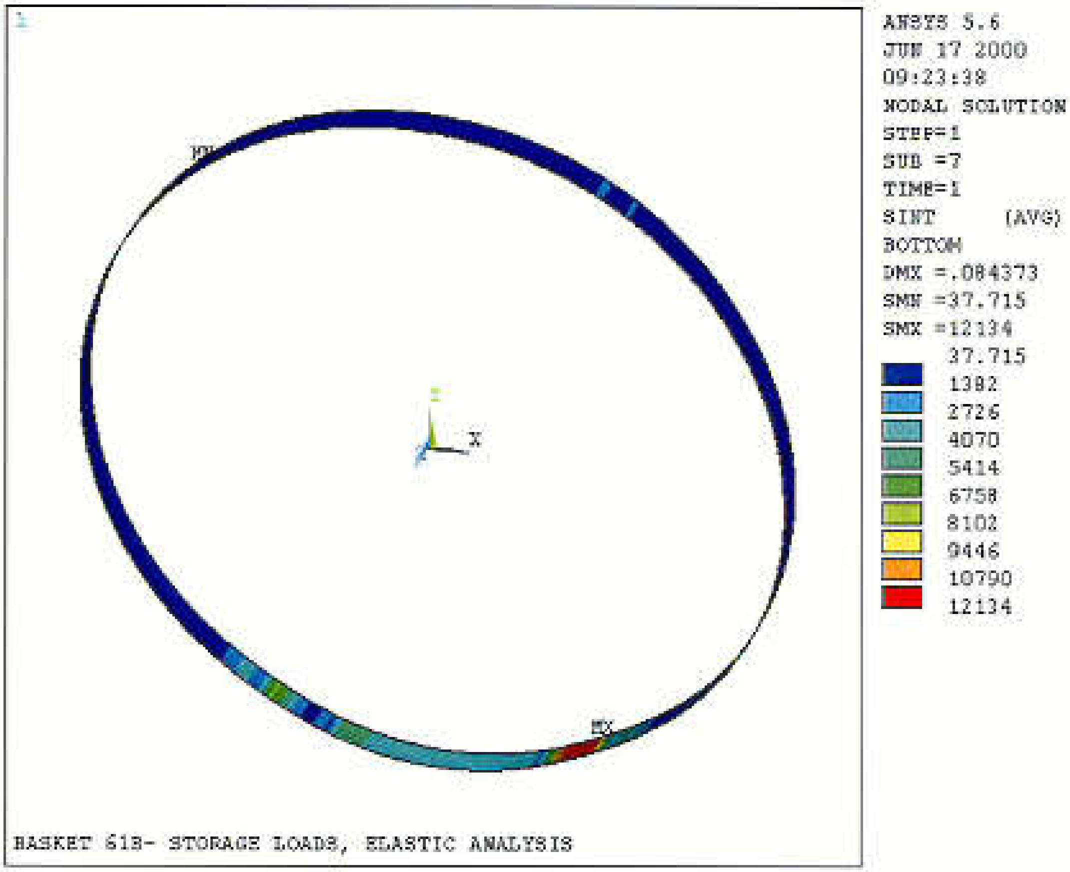


Figure K.3.6-21
Canister Shell Membrane + Bending Stress
(2g axial + 2g transverse + 2g vertical, Operation / Storage Load)

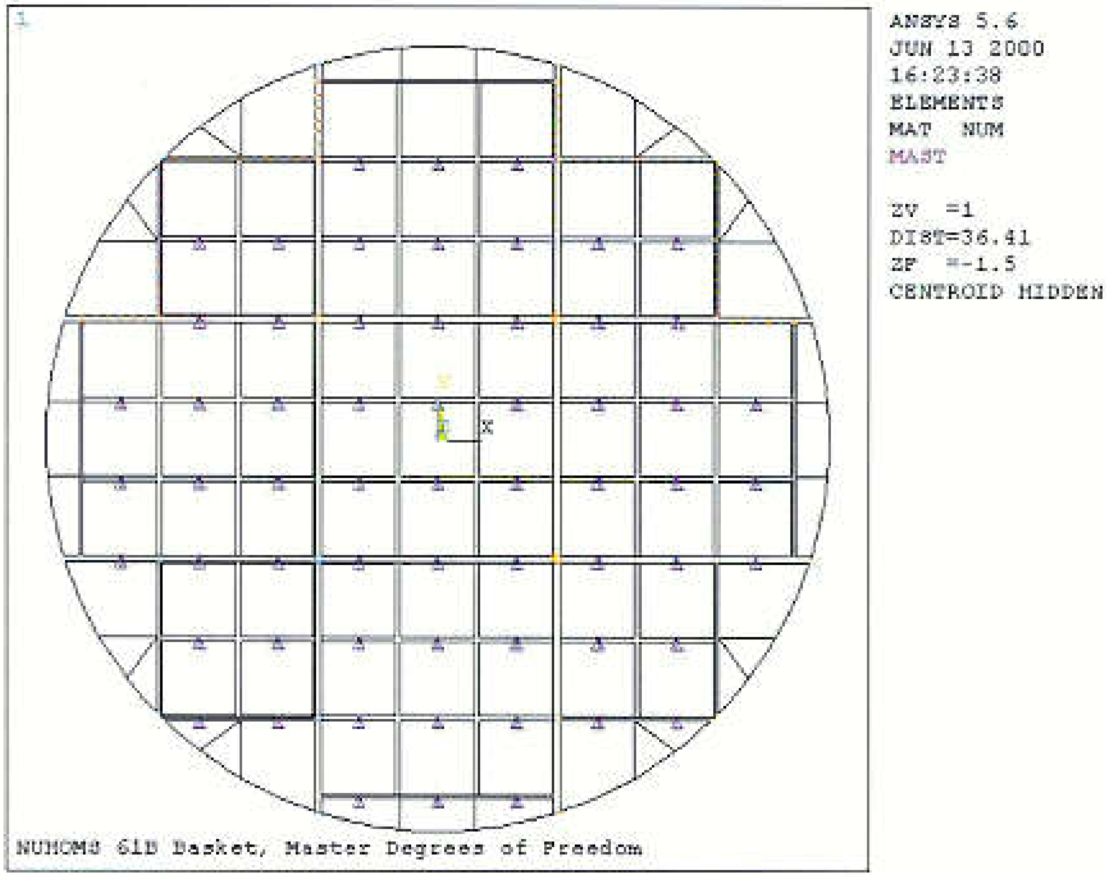


Figure K.3.6-22
NUHOMS 61B Master Degree-of-Freedom for Modal Analysis

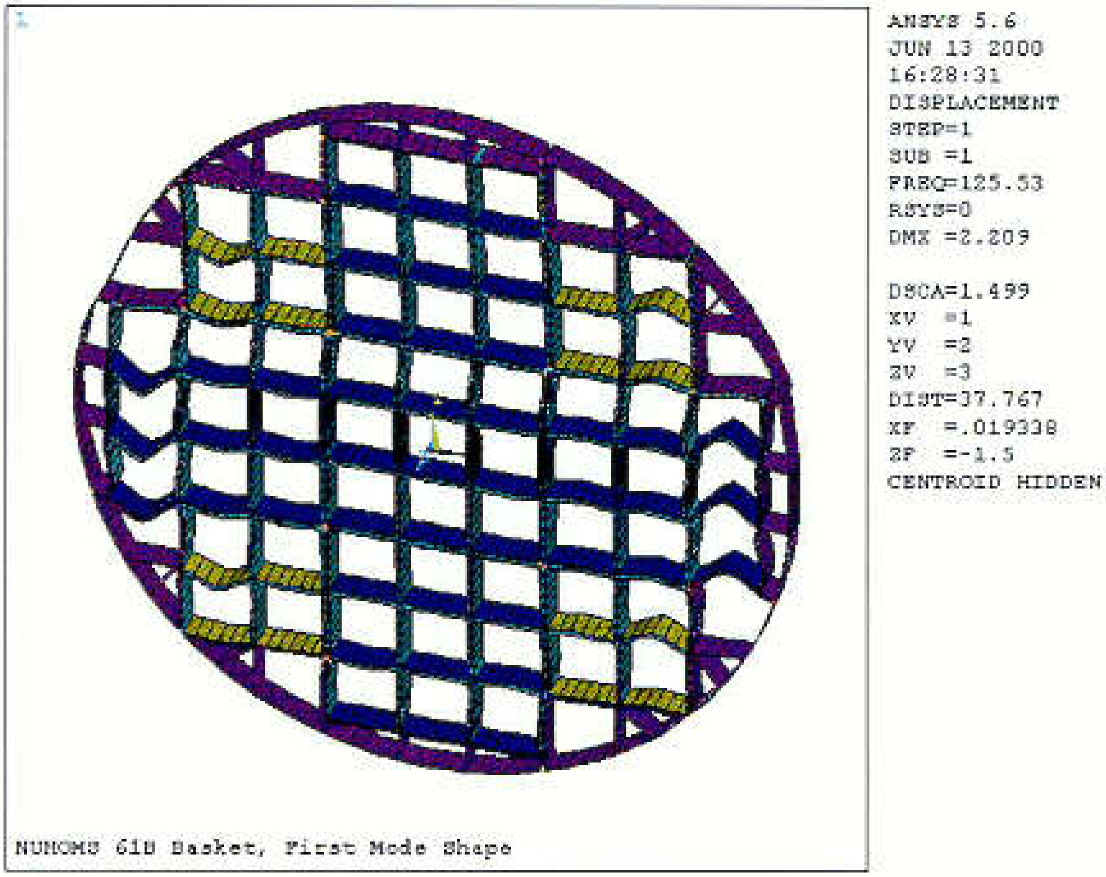


Figure K.3.6-23
NUHOMS 61B Basket Modal Analysis, First Mode Shape

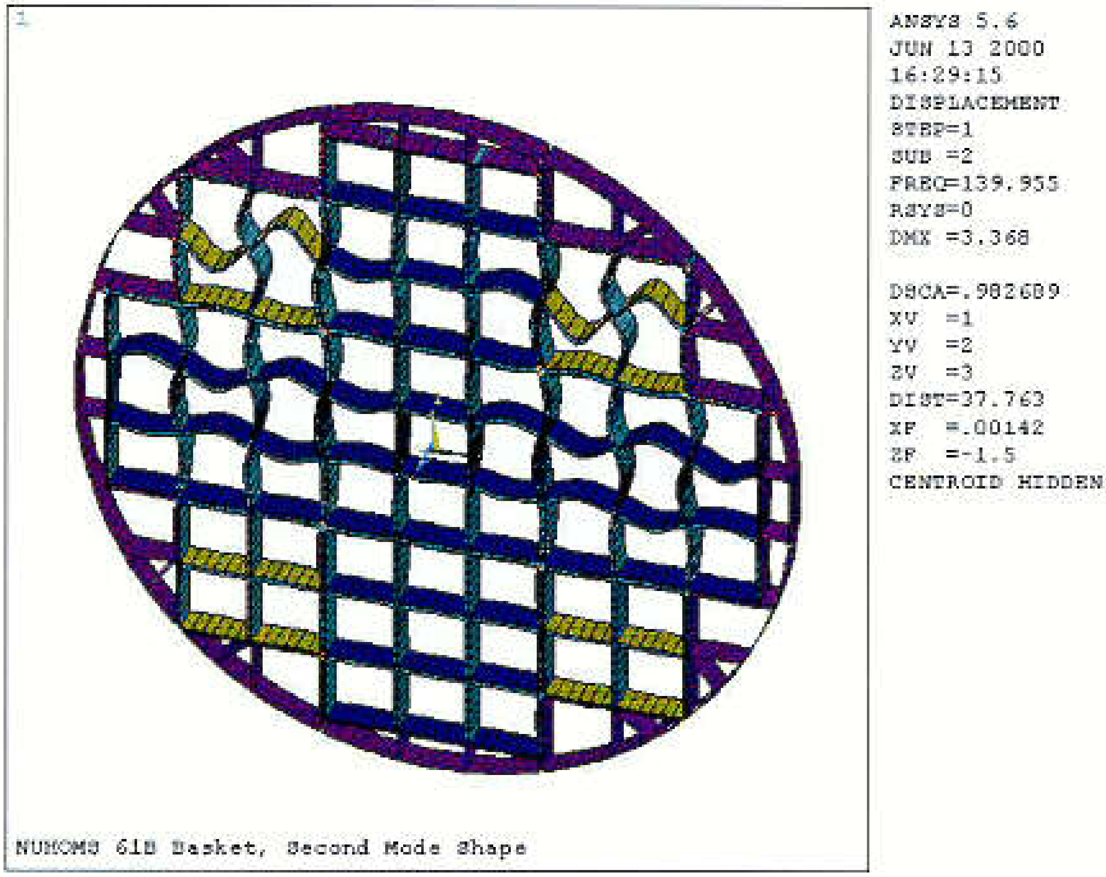


Figure K.3.6-24
NUHOMS 61B Basket Modal Analysis, Second Mode Shape

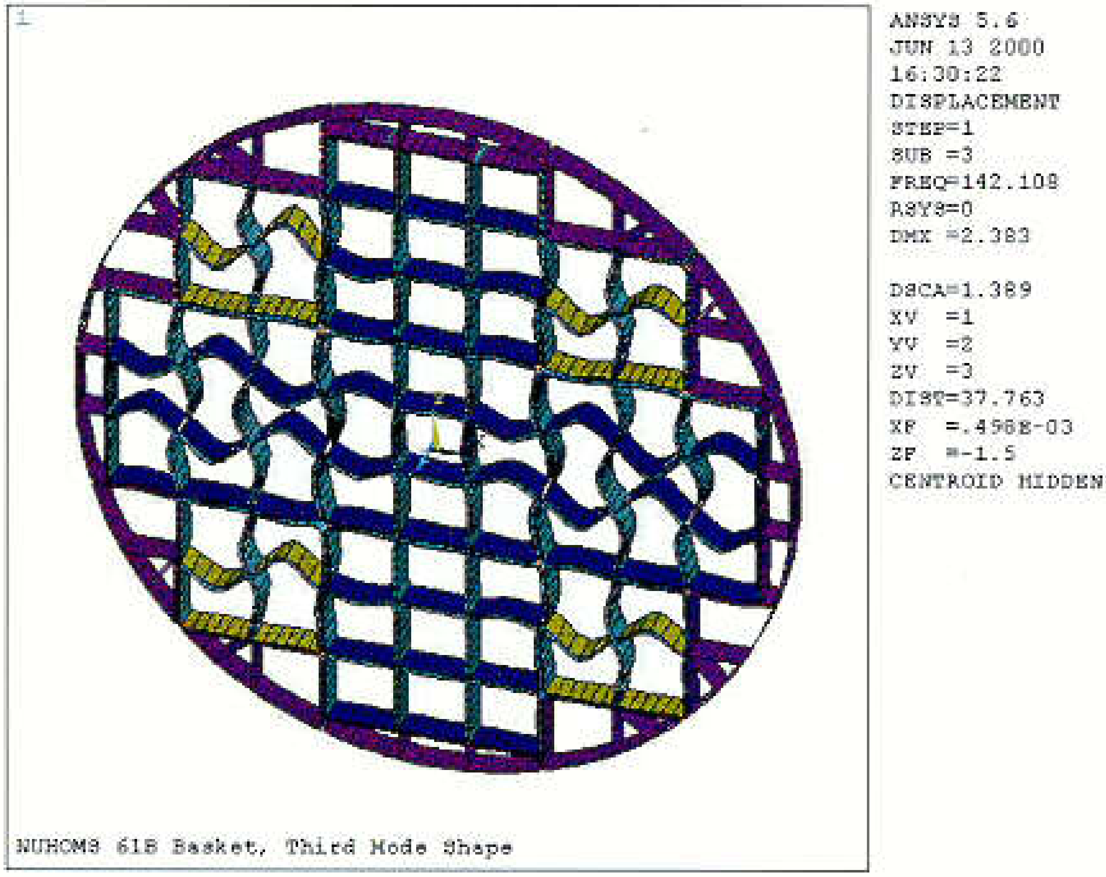


Figure K.3.6-25
NUHOMS 61B Basket Modal Analysis, Third Mode Shape

K.3.7 Structural Analysis (Accidents)

The design basis accident events specified by ANSI/ANS 57.9-1984, and other credible accidents postulated to affect the normal safe operation of the standardized NUHOMS® system are addressed in this section. Analyses are provided for a range of hypothetical accidents, including those with the potential to result in an annual dose greater than 25 mrem outside the owner controlled area in accordance with 10CFR72. The postulated accidents considered in the analysis and the associated NUHOMS® components affected by each accident condition are shown in Table K.3.7-1.

In the following sections, each accident condition is analyzed to demonstrate that the requirements of 10CFR72.122 are met and that adequate safety margins exist for the standardized NUHOMS® system design. The resulting accident condition stresses in the NUHOMS® system components are evaluated and compared with the applicable code limits set forth in Section 3.2 of the CSAR. Where appropriate, these accident condition stresses are combined with those of normal operating loads in accordance with the load combination definitions in Tables 3.2-5, 3.2-6, and 3.2-7 of the CSAR. Load combination results for the HSM, DSC, and transfer cask and the evaluation for fatigue effects are presented in Section K.3.7.10.

The postulated accident conditions addressed in this section include:

A. Reduced HSM air inlet and outlet shielding. (K.3.7.1)

B. Tornado winds and tornado generated missiles. (K.3.7.2)

C. Design basis earthquake. (K.3.7.3)

D. Design basis flood. (K.3.7.4)

E. Accidental transfer cask drop with loss of neutron shield. (K.3.7.5)

F. Lightning effects. (K.3.7.6)

G. Debris blockage of HSM air inlet and outlet opening. (K.3.7.7)

H. Postulated DSC leakage. (K.3.7.8)

I. Pressurization due to fuel cladding failure within the DSC. (K.3.7.9)

K.3.7.1 Reduced HSM Air Inlet and Outlet Shielding

This postulated accident is the partial loss of shielding for the HSM air inlet and outlet vents provided by the adjacent HSM. All other components of the NUHOMS® system are assumed to be functioning normally.

There are no structural consequences that affect the safe operation of the NUHOMS® system resulting from the separation of the HSMs. The thermal effects of this accident results from the blockage of HSM air inlet and outlet openings on the HSM side walls in contact with each other. This would block the ventilation air flow provided to the HSMs in contact from these inlet and outlet openings. The increase in spacing between the HSM on the opposite side from 6 inches to 12 inches, will reduce the ventilation air flow resistance through the air inlet and outlet openings on these side walls, which will partially compensate the ventilation reduction from the blocked side. However, the effect on the DSC, HSM and fuel temperatures is bounded by the complete blockage of air inlet and outlet openings described in Section K.3.7.7.

K.3.7.2 Tornado Winds/Tornado Missile

The applicable design parameters for the design basis tornado (DBT) are specified in Section 3.2.1 of the CSAR. The determination of the tornado wind and tornado missile loads acting on the HSM are detailed in Section 3.2.2 of the CSAR. The end modules of an array utilize shield walls to resist tornado wind and missile loads. For this conservative generic analysis, the tornado loads are assumed to act on a single free-standing HSM (with two end shield walls and a rear shield wall). This case conservatively envelopes the effects of wind on an HSM array. The transfer cask is also designed for the tornado wind and tornado missile loads defined in Section 3.2.2 of the CSAR. Thus, the requirements of 10CFR72.122 are met.

For DBT wind and missile effects, the HSM is more stable when loaded with a heavier NUHOMS®-61BT DSC since the overturning moment is not a function of the DSC weight while the resisting moment increases with the increased payload. The increased DSC weight does not have any effect on HSM sliding stability, since the weight terms on either side of the sliding equation presented in CSAR Section 8.2.2 cancel out. Thus, the analyses presented in CSAR Section 8.2.2 for DBT winds and missile effects remains bounding.

K.3.7.3 Earthquake

As discussed in Section 3.2.3 and as shown in Figure 8.2-2 of the CSAR, the peak horizontal ground acceleration of 0.25g and the peak vertical ground acceleration of 0.17g are utilized for the design basis seismic analysis of the NUHOMS® components. Based on NRC Reg. Guide 1.61 [3.15], a damping value of three percent is used for the DSC seismic analysis. Similarly, a damping value of seven percent for DSC support steel and concrete is utilized for the HSM. An evaluation of the frequency content of the loaded HSM is performed to determine the dynamic amplification factors associated with the design basis seismic response spectra for the NUHOMS® HSM and DSC. The dominant structural frequencies are calculated by conservatively factoring the frequencies in the existing CSAR Section8 HSM analysis to account for the heavier NUHOMS®-61BT DSC. The resulting lateral direction frequencies are 20.7 Hz and 31.4 Hz for the DSC on the support structure and HSM concrete structure, respectively. Table 1 of NRC Regulatory Guide 1.60 requires amplification factors for these structural frequencies, which result in conservative horizontal accelerations of 0.37g and 0.26g, respectively. The dominant vertical frequencies of the loaded HSM exceed 33 Hz, corresponding to the zero period acceleration of 0.17g vertical.

The dominant frequencies of the HSM and DSC inside the HSM are determined by scaling the response spectra analysis results for an analytical model identical to that shown in Figure 8.1-22 of the CSAR.

K.3.7.3.1 DSC Seismic Evaluation

As discussed above, the maximum calculated seismic accelerations for the DSC inside the HSM are 0.37g horizontally and 0.17g vertically. An analysis using these seismic loads shows that the DSC will not lift off the support rails inside the HSM. The resulting stresses in the DSC shell due to vertical and horizontal seismic loads are also determined and included in the appropriate load combinations. The seismic evaluation of the DSC is described in the paragraphs that follow. The DSC basket and support structure are also subjected to the calculated DSC seismic reaction loads as discussed in Sections K.3.7.3.2 and K.3.7.3.4, respectively.

K.3.7.3.1.1 DSC Natural Frequency Calculation

Two natural frequencies, each associated with a distinct mode of vibration of the DSC are evaluated. These two modes are the DSC shell cross-sectional ovalling mode and the mode with the DSC shell bending as a beam.

K.3.7.3.1.1.1 DSC Shell Ovalling Mode

The natural frequency for the DSC shell ovalling mode is determined from the Blevins [3.16] correlation as follows.

$$f = \frac{\lambda_i}{2\pi R}\sqrt{\frac{E}{\mu\,(1-\nu^2)}} \qquad \text{(Blevins, Table 12-1, Case 3)}$$

Where:

R = 33.375 in., DSC mean radius

E = 26.5E6 psi, Youngs Modulus

ν = 0.3, Poisson's ratio

$$\lambda_i = 0.289\,\frac{t}{R}\,\frac{i(i^2-1)}{\sqrt{1+i^2}}$$

t = 0.5 in., Thickness of DSC shell

μ = 0.288/g lb/in^3, Steel mass density

The lowest natural frequency corresponds to the case when i = 2.

Hence: λ_2 = 0.0116 sec.

Substituting gives: f = 10.9 Hertz

The resulting spectral accelerations in the horizontal and vertical directions for this DSC ovalling frequency are less than 1.0g and 0.68g, respectively.

K.3.7.3.1.1.2 DSC Beam Bending Mode

The DSC shell is conservatively assumed to be simply supported at the two ends of the DSC. The beam bending mode natural frequency of the DSC was calculated from the Blevins correlation:

$$f_i = \frac{\lambda_i^2}{2\pi L^2}\sqrt{\frac{EI}{m}}$$ (Blevins, Table 8.1, Case 5)

E = 26.5E6 psi, Young's Modulus

I = 58,400 in.^{4}, DSC moment of inertia

L = 186.5 in., Total length of DSC

m = 88,390/186.5g = 474/g lb./in.

λ = $i\pi$; for lowest natural frequency, i = 1

Substituting yields: f_1 = 50.7 Hertz.

The DSC spectral accelerations at this frequency correspond to the zero period acceleration. These seismic accelerations are bounded by those of the ovalling mode frequency that are used in the subsequent stress analysis of the DSC shell.

K.3.7.3.1.2 DSC Seismic Stress Analysis

With the DSC resting on the support rails inside the HSM, the stresses induced in the DSC shell are calculated due to the 1.0g horizontal and 0.68g vertical seismic accelerations, conservatively increased by a factor of 1.5 to account for the effects of possible multimode excitation. For the stress evaluation of the DSC shell due to seismic accelerations in the lateral direction, the equivalent static acceleration of 1.5g is multiplied by 2, based on the conservative assumption that the DSC is supported by only one of the two support rails inside the HSM during the horizontal earthquake. Thus, the DSC shell is qualified to seismic accelerations of 3.0g horizontal and 1.0g vertical. The DSC shell stresses obtained from the analyses of vertical and horizontal seismic loads are summed absolutely. See Table K.3.7-12 for the Level C seismic stress evaluation of the NUMHOS®-61BT DSC. The seismic load combination includes deadweight + pressure + 3g horizontal and 1g vertical (load combinations HSM-7 and HSM-8 as shown in Table K.3.7-15).

As stated, in Section 4.2.3.2 of the CSAR, an axial retainer is included in the design of the DSC support system inside the HSM to prevent sliding of the DSC in the axial direction during a postulated seismic event. The stresses induced in the DSC shell and bottom cover plate due to the restraining action of this retainer for a horizontal seismic load, applied along the axis of the DSC, are included in the seismic response evaluation of the DSC shell assembly.

The stability of the DSC against lifting off one of the support rails during a seismic event is evaluated by performing a rigid body analysis, using the 0.37g horizontal and 0.17g vertical input accelerations. The factor of 1.5 used in the DSC analysis to account for multimode behavior need not be included in the seismic accelerations for this analysis, as the potential for lift off is due to rigid body motion, and no frequency content effects are associated with this action. The horizontal equivalent static acceleration of 0.37g is applied laterally to the center of gravity of the DSC. The point of rigid body rotation of the DSC is assumed to be the center of the support rail, as shown in Figure K.3.7-1. The applied moment acting on the DSC is calculated by summing the overturning moments. The stabilizing moment, acting to oppose the applied moment, is calculated by subtracting the effects of the upward vertical seismic acceleration of 0.17g from the total weight of the DSC and summing moments at the support rail. Since the stabilizing moment calculated below is greater than that of the applied moment, the DSC will not lift off the DSC support structure inside the HSM.

Referring to Figure K.3.7-1, the factor of safety associated with DSC lift-off is calculated as follows:

$$M_{am} = yF_H$$

and $$M_{sm} = (F_{v1} - F_{v2})x$$

Where: M_{am} = The applied seismic moment

M_{sm} = The stabilizing moment

All other variables are defined in Figure K.3.7-1.

Substituting yields: M_{am} = 951.7 K-in.

and M_{sm} = 1232.5 K-in.

Thus, the factor of safety (SF) against DSC lift off from the DSC support rails inside the HSM obtained from this bounding analysis is:

$$SF = \frac{M_{sm}}{M_{am}} = 1.30$$

K.3.7.3.2 Basket Seismic Evaluation

The basket seismic analysis is performed using the models which were developed for normal and off-normal evaluations. A description of the seismic models, applied loads and associated results is presented in Section K.3.6.1.3.4 B. The basket natural frequency is also calculated in Section K.3.6.1.3.4 D.

K.3.7.3.3 HSM Seismic Evaluation

To evaluate the seismic response of the HSM with the NUHOMS®-61BT DSC, analysis results of the BWR HSM evaluated in Section 8 of the CSAR are factored to account for both increases in accelerations due to frequency shifts and increases in inertia. This is done because the NUHOMS®-61BT DSC is heavier than the DSCs evaluated in Section 8 of the CSAR. The maximum factor for the limiting frequency shift acceleration effects is 1.032. The factor for inertia effects is 1.105. The combined factor is 1.14. Seismic results are included in the load combinations. Results for the most limiting components and the most limiting load combinations are presented in Table K.3.7-2.

An analysis is also performed to establish the worst case factor of safety against overturning and sliding for a single, free-standing module. This analysis consists of comparing the stabilizing moment produced by the weight of the HSM and DSC, reduced by 17 percent to account for the upward vertical seismic acceleration, against the overturning moment produced by applying the 0.37g load at the centroid of the HSM and DSC. For sliding of the HSM, the horizontal force of 0.37g acceleration is compared against the frictional resisting force of the foundation slab. In this manner, the factor of safety against sliding is established. The concrete coefficient of friction is taken as 0.6 as defined in Section 11.7.4.3 of ACI 318-83 [3.17].

The details of the seismic evaluation of the HSM when loaded with NUHOMS®-61BT DSC are described in the paragraphs that follow.

K.3.7.3.3.1 HSM Frequency Analysis

As shown in CSAR Section 8.2.3.1 paragraph B, the lowest horizontal and vertical structural frequencies calculated for a single free standing HSM are 21.7 Hz and 47.0 Hz, respectively. An increase in the NUHOMS®-61BT DSC weight of 11% relative to the NUHOMS®-52B DSC results in a conservative frequency shift estimated to be approximately 5%. The adjusted frequencies are 20.7 Hz and 44.7 Hz, respectively. The corresponding horizontal and vertical spectral accelerations are 0.37g and 0.17g.

K.3.7.3.3.2 HSM Seismic Response Spectrum Analysis

The existing HSM structural qualification evaluations provided in Sections 8.1 and 8.2 of the CSAR used a NUHOMS® DSC weight of 80,000 lbs. The weight of the NUHOMS®-61BT DSC is approximately 11% greater. The effects of the increased weight are evaluated by scaling the governing load case stress ratios (or demand/capacity ratios) that are affected by the weight increase to ensure that ratios are less than 1.0. The scaled stress ratios are reported in Table K.3.7-2.

K.3.7.3.3.3 HSM Overturning Due to Seismic

The heavier weight of the NUHOMS®-61BT DSC does not have any effect on the HSM overturning stability due to seismic forces, since the HSM and DSC weight terms cancel out on either side of the overturning equation presented in CSAR Section 8.2.3. Thus, the factor of safety against overturning due to seismic remains unchanged at 1.24 as evaluated in CSAR Section 8.2.3.

K.3.7.3.3.4 HSM Sliding Due to Seismic

The heavier weight of the NUHOMS®-61BT DSC does not have any effect on the HSM sliding stability due to seismic forces, since the HSM weight terms cancel out on either side of the sliding equation presented in CSAR Section 8.2.3. Thus, the factor of safety against sliding due to seismic remains unchanged at 1.34 as evaluated in CSAR Section 8.2.3.

K.3.7.3.4 DSC Support Structure Seismic Evaluation

Using the same method discussed in Section K.3.7.3.3, CSAR Section 8 results are scaled to account for the heavier NUHOMS®-61BT DSC. The evaluation includes the support frame, cross members, rails, anchor bolts, and cross member connections.

K.3.7.3.4.1 DSC Support Structure Natural Frequency

The lowest structural frequency of the DSC support structure inside the HSM is dominated by the mass of the DSC. The DSC and support structure are included in the HSM analytical model. The dominant horizontal and vertical frequencies of the DSC/DSC support structure reported in CSAR Section 8 are 21.7 Hz and 47.0 Hz, respectively. As discussed in Section K.3.7.3.3.1, a conservative frequency shift is estimated to be 5%. The adjusted frequencies are 20.7 Hz and 44.7 Hz.

K.3.7.3.4.2 DSC Support Structure Seismic Response Spectra Analysis

Using the same method discussed in Section K.3.7.3.3.2, the stress ratios in the support frame columns, cross members and rails for the governing load combinations are reported in Table K.3.7-2.

K.3.7.3.5 DSC Axial Retainer Seismic Evaluation

The DSC axial retainer detail, located inside the HSM access opening, is shown on the Appendix E drawings. The retainer bears on the end of the DSC and transfers axial seismic loads to a steel rod/plate assembly that is bolted onto the HSM access opening door. The DSC axial retainer is bolted in place following transfer of the DSC to the HSM and placement of the shielded door.

The clearance between the DSC axial retainer and the DSC is designed for the maximum DSC thermal growth that occurs during the postulated HSM blocked vent case, as discussed in Section 8.2.7 of the CSAR. During normal storage there is a small (1/8 to 1/4 inch) gap that will allow movement of the DSC relative to the HSM. This motion produces a small increase in the DSC axial force due to seismic loads, and has been included in the design of the DSC.

The DSC will be subjected to maximum seismic accelerations equal to the rigid range spectral accelerations of 0.37g horizontal and 0.17g vertical. The seismic load acting on the axial retainer is computed considering the spectral accelerations less the friction force between the DSC Support Structure rails and the DSC. The DSC is supported by the DSC Support Structure on rails that are at 30 degrees on either side of the vertical centerline. The rail orientation is considered in determining the normal force in the friction force calculation. The friction force is calculated using the minimum net vertical acceleration, which is the acceleration due to gravity minus the maximum vertical seismic acceleration or (1g – 0.17g) = 0.83g and a coefficient of friction of 0.25. In order to account for the impact load from the DSC onto the axial retainer, an impact factor of 1.50 is considered. The load on the axial retainer is computed as follows:

$$P = (WS_a - F_f)1.50$$

Where,

P = seismic load acting on the axial retainer, kips

W = DSC weight, conservatively assumed to be 88.4 kips

S_a = horizontal rigid range spectral acceleration of 0.37g

N	=	normal force on the rails due to the weight of the DSC = $W_f G_v/\cos 30°$ = (88.4 kips)(0.83g)/cos30° = 84.7 kips
F_f	=	friction force between the DSC and the rails = NC_f = (84.7 kips)(0.25) = 21.2 kips
G_v	=	minimum net vertical acceleration = 0.83g
W_f	=	Weight of DSC for friction calculation, 88.4 kips
C_f	=	Coefficient of friction between the DSC Support Structure rail and the DSC, 0.25
P	=	[(88.4 kips)(0.37g) – 21.2 kips]1.50 = 17.3 kips

The controlling design element in the axial retainer is the load on the 2" diameter steel rod that is subjected to compression loading. In accordance with AISC and ANSI/ANS 57.9, the allowable compressive stress using a 1.6 allowable stress increase factor is 18.7 ksi. The calculated compression stress is 5.5 ksi, so the steel rod is within the allowable stress.

K.3.7.3.6 Transfer Cask Seismic Evaluation

The effects of a seismic event occurring when a loaded NUHOMS®-52B DSC is resting inside the transfer cask are described in CSAR Section 8.2.3 paragraph D. The stabilizing moment to prevent overturning of the cask/trailer assembly due to the 0.25g horizontal and 0.17g vertical seismic ground accelerations is calculated and compared to the dead weight stabilizing moment. The results of this analysis show that there is a factor of safety of at least 2.0 against overturning that ensures that the cask/trailer assembly has sufficient margin for the design basis seismic loading. This factor of safety against overturning due to seismic remains bounding for the NUHOMS®-61BT DSC as discussed above for the HSM in Section K.3.7.3.3.3.

K.3.7.4 Flood

Since the source of flooding is site specific, the exact source, or quantity of flood water, should be established by the licensee. However, for this generic evaluation of the DSC and HSM, bounding flooding conditions are specified that envelop those that are postulated for most plant sites. As described in Section 3.2 of the CSAR, the design basis flooding load is specified as a 50 foot static head of water and a maximum flow velocity of 15 feet per second. Each licensee should confirm that this represents a bounding design basis for their specific ISFSI site.

K.3.7.4.1 HSM Flooding Analysis

For flooding effects, the HSM is more stable when loaded with the heavier NUHOMS®-61BT DSC since the overturning moment is not a function of the DSC weight while the resisting moment increases with the increased payload. The increased DSC weight does not have any effect on HSM sliding stability, since the weight terms on either side of the sliding equation presented in CSAR Section 8.2.4 cancel out. Thus, the analyses presented in CSAR Section 8.2.4 for flooding effects remains bounding.

K.3.7.4.2 DSC Flooding Analyses

The DSC is evaluated for the design basis fifty foot hydrostatic head of water producing external pressure on the DSC shell and outer cover plates. To conservatively determine design margin which exists for this condition, the maximum allowable external pressure on the DSC shell is calculated for Service Level A stresses using the methodology presented in NB-3133.3 of the ASME Code [3.1]. The resulting allowable pressure of 39.1 psi is 1.8 times the maximum external pressure of 21.7 psi due to the postulated fifty foot flood height. Therefore, buckling of the DSC shell will not occur under the worst case external pressure due to flooding.

The DSC shell stresses for the postulated flood condition are determined using the ANSYS analytical model shown in CSAR Figure 8.1-9a and CSAR Figure 8.1-9b. The 21.7 psig external pressure is applied to the model as a uniform pressure on the outer surfaces of the top cover plate, DSC shell and bottom cover plate. The maximum DSC shell primary membrane stress intensity for the 21.7 psi external pressure is 1.67 ksi which is considerably less than the Service Level C allowable primary membrane stress of 21.7 ksi. The maximum membrane plus bending stress in the flat heads of the DSC occurs in the top cover plate. The maximum membrane plus bending stress in the top cover plate is 0.56 ksi. This value is considerably less than the ASME Service Level C allowable of 32.6 ksi for primary bending. These stresses are combined with the appropriate loads to formulate load combinations. The resulting total stresses for the DSC are reported in Section 8.2.10 of the CSAR.

K.3.7.5 Accidental Cask Drop

This section addresses the structural integrity of the standardized NUHOMS® on-site transfer cask, the DSC and its internal basket assembly when subjected to postulated cask drop accident conditions.

Cask drop evaluations include the following:

- DSC Shell Assembly (K.3.7.5.2),
- Basket Assembly (K.3.7.5.3),

- On-Site Transfer Cask (K.3.7.5.4), and
- Loss of the Transfer Cask Neutron Shield (K.3.7.5.5).

The DSC shell assembly, transfer cask, and loss of neutron shield evaluations are based on the approaches and results presented in the CSAR. The basket assembly cask drop evaluation is presented in more detail since the basket assembly is a new design and uses slightly different analytical approaches for qualification.

A short discussion of the effect of the NUHOMS®-61BT DSC on the transfer operation, accident scenario and load definition is presented in Section K.3.7.5.1.

K.3.7.5.1 General Discussion

Cask Handling and Transfer Operation

Various transfer cask drop scenarios have been evaluated in Section 8.2.5 of the CSAR. The NUHOMS®-61BT DSC is heavier than the NUHOMS®-52B DSC. Therefore, the expected g loads for the postulated drop accidents would be lower. However, for conservatism, the g loads used for the NUHOMS®-52B analyses are also used for the NUHOMS®-61BT DSC analyses. See Section 8.2.5 of the CSAR.

Cask Drop Accident Scenarios

In spite of the incredible nature of any scenario that could lead to a drop accident for the transfer cask, a conservative range of drop scenarios are developed and evaluated. These bounding scenarios assure that the integrity of the DSC and spent fuel cladding is not compromised. Analyses of these scenarios demonstrate that the transfer cask will maintain the structural integrity of the DSC pressure containment boundary. Therefore, there is no potential for a release of radioactive materials to the environment due to a cask drop. The range of drop scenarios conservatively selected for design are:

1. A horizontal side drop or slap down from a height of 80 inches.
2. A vertical end drop from a height of 80 inches onto the top or bottom of the transfer cask (two cases).
3. An oblique corner drop from a height of 80 inches at an angle of 30° to the horizontal, onto the top or bottom corner of the transfer cask. This case is not specifically evaluated. The side drop and end drop cases envelope the corner drop.

Cask Drop Accident Load Definitions

Same as CSAR.

Cask Drop Surface Conditions

Same as CSAR.

K.3.7.5.2 DSC Shell Assembly Drop Evaluation

The shell assembly consists of the DSC shell, the shield plugs, and the top and bottom inner and outer cover plates. The shell assembly drop evaluation is presented in three parts:

1. DSC shell assembly horizontal drop analysis,
2. DSC shell assembly vertical drop analysis, and
3. DSC shell stability analysis.

K.3.7.5.2.1 DSC Shell Assembly Horizontal Drop Analysis

The DSC shell assembly is analyzed for the postulated horizontal side drop using the ANSYS 3-D models of the DSC shell assembly discussed in Section 3.6.1.2. Half-symmetry (180°) models of the top end and bottom end sections of the DSC shell assembly are developed based on the models developed for the end drops shown in Figure 8.1-9a and Figure 8.1-9b of the CSAR. Each model includes one-half of the height of the cylindrical shell. Each of the DSC shell assembly components is modeled using ANSYS solid 3-D elements. The full weight of the DSC is conservatively assumed to drop directly onto a single rail. Elastic-plastic analyses are performed and stresses are determined for each DSC shell assembly component. The NUHOMS®-61BT DSC shell stresses in the region of the basket assembly are also analyzed for the postulated horizontal side drop conditions. This analysis and results are presented in Section K.3.7.5.3.1.

K.3.7.5.2.2 DSC Shell Assembly Vertical Drop Analysis

For this drop accident case, the transfer cask is assumed to be oriented vertically and dropped onto a uniform unyielding surface. The vertical cask drop evaluation conservatively assumes that the transfer cask could be dropped onto either the top or bottom surfaces. No credit is taken for the energy absorbing capacity of the cask top or bottom cover plate assemblies during the drop. Therefore, the DSC is analyzed as though it is dropped on to an unyielding surface. The principal components of the DSC and internals affected by the vertical drop are the DSC shell, the inner and outer top cover plates, the shield plugs, and the inner and outer bottom cover plates.

The end drop with the bottom end of the DSC oriented downward is the more credible of the two possible vertical orientations. Nevertheless, an analysis for the DSC top end drop accident is also performed. For a postulated vertical drop, membrane stresses in the DSC shell and local stresses at the cover plate weld region discontinuities are evaluated.

K.3.7.5.2.3 DSC Shell Assembly Stress Analysis

The ANSYS analytical models of the DSC shell assembly as described in Section K.3.6.1.2 and shown in Figure 8.1-9a and Figure 8.1-9b of the CSAR are used to determine the vertical end drop accident stresses in the DSC shell, the inner cover plates, the outer cover plates, and the shield plugs. The models consist of 90° quarter symmetry models and include one-half of the height of the cylindrical shell. To capture the maximum stress state in the DSC assembly components, each model was analyzed for end drop loading on the opposite end (i.e., the bottom end model was analyzed for top end drop, and the top end model was analyzed for bottom end drop). In these drop orientations, the end plates are supported at the perimeter by the shell. For the top and bottom end drops, the nodal locations on the impacted end are restrained in the vertical direction. An equivalent static linear elastic analysis is conservatively used for the vertical end drop analyses. Inertia loadings based on forces associated with the 75g deceleration are statically applied to the models. Analyses show that the stresses in the DSC cover plates and shield plugs are low. These low stresses occur since the bottom end drop, the inner and outer top cover plates are supported by the top shield plug. During a top end drop, the outer top cover plate is assumed to be supported by the unyielding impacted surface and is subjected to a uniform bearing load imposed by the DSC internals. The same is true for the DSC bottom outer cover plate and shield plug for the bottom end drop. The highest stresses occur in the DSC shell and bottom inner cover plate. The maximum stresses in the bottom inner cover plate result from the top end vertical drop condition, in which the bottom inner cover plate is supported only at the edges. The maximum DSC shell membrane stresses, which occur near the top end of the DSC shell area, result from the accelerated weight of the DSC shell and the bottom end (for top end drop case) or top end (for the bottom end drop case) assemblies.

A summary of the calculated stresses for the main components of the DSC and associated welds is provided in Table K.3.7-3.

K.3.7.5.2.4 DSC Shell Stability Analysis

The stability of the DSC shell for a postulated vertical drop impact is also evaluated. For Level D conditions, the allowable axial stress in the DSC shell is based on Appendix F of the ASME Code. The maximum axial stress in the DSC shell obtained from the 75g end drop analyses is 10.31 ksi. The allowable axial stress is 12.0 ksi. Therefore, buckling of the DSC shell for a 75g vertical deceleration load does not occur.

K.3.7.5.3 Basket Assembly Drop Evaluation

As discussed in previous chapters, the primary structural components of the basket assembly include:

- Holddown ring,
- Fuel compartments,
- Outer wrappers,
- Basket rails,
- Basket rail to fuel compartment rail studs, and
- Poison plate support insert welds.

The DSC resides in the transfer cask for all drop conditions. The DSC is supported horizontally in the transfer cask by two cask rails that are integral to the cask wall. The effect of these cask rails are included in the horizontal drop evaluations.

The evaluation is presented in three parts:

1. Basket assembly horizontal drop analysis which includes a stress evaluation of the basket, basket rails, and basket rail studs.
2. Basket assembly vertical drop analysis which includes a stress evaluation of the basket (fuel compartment tubes and outer wrappers), basket rail, insert welds, and the holddown ring. Holddown ring stability is also demonstrated for the vertical loading condition.
3. Basket assembly stability which includes a buckling evaluation of the wall between fuel compartments at the most highly loaded location for the most challenging drop orientation and buckling of the support rails. Fuel compartment stability is demonstrated independently by performing the evaluation using both a finite element analysis approach and hand calculation.

K.3.7.5.3.1 Basket Assembly Horizontal Drop Analysis

K.3.7.5.3.1.1 Basket and Basket Rail Stress Analysis

The basket and DSC are analyzed for two modes of side drops using the ANSYS finite element model described in Section K.3.6.1.3.1. First, the cask is assumed to drop away from the transfer cask support rails. Under this condition, 45, 60 and 90 degree orientation side drops are assumed to bound the possible maximum stress cases. Second, the side drop occurs on the transfer cask support rails at 161.5 and 180 degree orientations. The lateral load orientation angles are defined in Figure K.3.6-5. The load resulting from the fuel assembly weight was applied as pressure on the plates. At 90 and 180 degree orientations, the pressure acted only on the horizontal plates while at other orientations, it was divided in components to act on horizontal and vertical plates. The pressures for different orientations are summarized in the Table K.3.7-4 for 1g acceleration.

The inertia load due to basket, rails and DSC dead weight is simulated using the density and appropriate acceleration. The poison plate weight is included by increasing the basket plate density.

The load distribution for 90, 180 , 45, 60 and 161.5 degree analyses are shown on Figure K.3.7-2 to Figure K.3.7-5.

Analysis and Results

A nonlinear stress analysis of the structural basket is conducted for computing the stresses for the 45, 60, 90, 161.5 and 180 degree drop orientations. A maximum load of 100g was applied in each analysis. The automatic time stepping program option "Autots" was activated. This option lets the program decide the actual size of the load-substep for a converged solution. Displacements, stresses and forces for each converged substep load were written on ANSYS result files. The program stops at the load substep when it fails to result in a converged solution. In all side drop cases the program gave converged solutions up to 100g load. Results were extracted at the load sub-step nearest to the maximum drop load of 75g. Maximum nodal stress intensities in the basket, rails and DSC are shown on Figure K.3.7-6 to Figure K.3.7-35 and summarized in Table K.3.7-5.

K.3.7.5.3.1.2 Basket Rail Stud Stress Analysis

It was observed from the side drop basket stress summary table that the maximum membrane stresses in the rail and basket occurred during 90-degree drop orientation. In other side drop orientations, membrane stresses were somewhat lower. Accordingly, the maximum shear stress in the rail stud are expected to occur due to the a 90 degree drop orientation. This seems reasonable since during this basket orientation, the fuel weight sits squarely on the largest number of basket panels. The rail stud stresses are therefore computed for a 90-degree side drop orientation. These stresses bound the stud stresses for other basket drop orientations.

The load resulting from the fuel assembly weight was applied as pressure on the basket panels. At the 90° orientation, the pressure acted only on the horizontal plates.

Finite Element Model Description

A three-dimensional finite element model of the basket, rails and DSC were constructed with the following modifications using the finite element model described in Section K.3.6.1.3.

- The couplings at the rail stud locations were replaced with ANSYS Pipe Elements.
- Shear stresses were considered critical in the rail stud weld (O.D. = 0.5" and I.D. = 0.3"). Therefore, the pipe real constant (equivalent thickness) was calculated based on the weld area. The solid stud area is greater than the weld area. Stresses will be lower in the solid area of the stud.
- All material properties, real constants and couplings of the remainder of the model are the same as used for the previous 90° side drop analysis.

The calculated maximum rail stud shear stress for the 90° side drop orientation (75g) is 17.43 ksi. Maximum rail stresses are included in the summary of stresses in Table K.3.7-5.

K.3.7.5.3.2 Basket Assembly Vertical Drop Analysis

During an end drop, the fuel assemblies and fuel compartments are forced against the bottom of the DSC/cask. It is important to note that, for any vertical or near vertical loading, the fuel assemblies react directly against the bottom or top end of the DSC/cask and not through the basket structure as in lateral loading. It is the dead weight of the basket only that causes axial compressive stress during an end drop. Axial compressive stresses are conservatively computed assuming all the weight will be taken by the compartment tubes and wrappers only. A conservative basket weight of 23.0 kips. (actual weight is 22.92 kips) is used in end drop stress calculations.

K.3.7.5.3.2.1 Component Stress Analysis

Compressive Stress At Fuel Compartment Tubes And Outer Wrappers

Total weight = 23.0 kips

Weight excluding holddown ring, SS inserts, poison plates, aluminum plates, and rails is 12.49 kips.

Section area = 12,490 /(164 x 0.29) = 262.62 in^2
Stress due to 1g = -23.0 / 262.62 = - 0.09 ksi
At 75g = - 0.09 ksi × 75 = - 6.75 ksi

Shear Stress in Plate Insert Weld

52 Inserts support the poison plate weight (3.26 kips)

Load/insert = 3.26 / 52 = 0.063 kips
Weld Shear Area = 0.707 x 4 x 0.125 = 0.3535 in^2
Shear stress (1g) = 0.063 / 0.3535 = 0.18 ksi
At 75g = 0.18 ksi × 75 = 13.5 ksi

Shear Stress in Rail Stud

During the 75\g end drop, the rail will support its own weight. However, the analysis conservatively assumes that the weight of the rail will be supported by the rail studs attached to the compartment outer boxes.

Weight of rails = 5.35 kips
Weld Shear Area = $\pi/4\ (0.5^2 - 0.3^2) = 0.126\ in^2$
Shear stress (1g) = 5.35 / (0.126 × 224) = 0.19 ksi
At 75g = 0.19 ksi × 75 = 14.25 ksi

Compressive Stress On Holddown Ring

Weight of hold down ring = 0.94 kips
Section area = 940/(14.5 x 0.29) = 223.5 in^2
Stress due to 1g = -23.0 / 223.5= - 0.1 ksi
At 75g = - 0.1 ksi × 75 = - 7.5 ksi

Results of Basket End Drop Analysis

Table 3.7.6 summarizes the basket structural analysis results due to the 75g vertical end drop accident condition.

K.3.7.5.3.2.2 - Holddown Ring Buckling Analysis

The buckling of 6.20" x 6.20" box and 12.96" x 12.96" box are evaluated below for 7.5 ksi axial compressive stress.

6.20" x 6.20" Box of Ring

As given in ASME Code, Subsection NF, Paragraph NF-3322-1(c)(2)(a)(Level A Condition) and modified as per Appendix F, Paragraph F-1334 (Level D Condition), the compressive stress limit for the accident condition (Level D) when KL/r is less than 120 and $S_u > 1.2\ S_y$ is:

$F_a = 2 \times S_y\ [0.47 - (KL/r)/444]$

Where:

$K = 2.1$ as recommended by AISC (Table C1.8.1). The box is assumed to be free at one end and fixed on the other end.

Plate thickness, $h = 0.375$ in.

Box outer width = 6.20 + 2 x 0.375 = 6.95"

$S_y = 19{,}400$ psi (at 500°F)

$I = (1/12)[\ 6.95^4 - 6.20^4] = 71.29$ in.^{4}

$A = 6.95^2 - 6.20^2 = \ 9.86$ in.^{2}

$r = (I/A)^{1/2} = 2.69$ in.

$KL/r = 2.1 \times 14.5 / 2.69 = 11.32$

Substituting the values given above,

$F_a = 2 \times 19{,}400\ [0.47 - (11.32)/444] = 17{,}246$ psi ≈ 17.25 ksi

The allowable buckling stress (17.25 ksi) is higher than the actual compressive stress (7.5 ksi), Therefore, buckling will not occur.

12.96" x 12.96" Box of Ring

Box outer width = 12.96 + 2 x 0.375 = 13.71 in.

$I = (1/12)[13.71^4 - 12.96^4] = 593.28$ in.^{4}

$A = 13.71^2 - 12.96^2 = 20.0$ in.^{2}

$r = (I/A)^{1/2} = 5.446$ in.

$KL/r = 2.1 \times 14.5 / 5.446 = 5.591$

$F_a = 2 \times 19{,}400\ [0.47 - (5.591)/444] = 17{,}747$ psi ≈ 17.75 ksi

The allowable buckling stress (17.75 psi) is higher than the actual compressive stress (7.75ksi). Therefore, buckling will not occur.

K.3.7.5.3.3 Basket Assembly Stability Analysis

Basket assembly stability which includes a buckling evaluation of the wall between fuel compartments at the most highly loaded location for the most challenging drop orientation and a buckling evaluation of the support rails is determined in this section. Fuel compartment stability is demonstrated by performing a buckling evaluation using an ANSYS finite element analysis approach. Additionally, an order of magnitude check on the fuel compartment stability is performed using a hand calculation methodology. An ANSYS finite element analysis approach is used to evaluate support rail buckling. A summary of the analysis results is presented in Section K.3.7.5.3.3.4.

K.3.7.5.3.3.1 Fuel Compartment Stability Demonstration Using Finite Element Analysis

Additional analyses are performed in this section to evaluate the outer basket plate stability when the lateral inertial loading is applied at various angles relative to the plates. Analyses are performed for vertical, 30, and 45 degree drop angles (Figure K.3.7-36).

The basic structural element of the basket is considered to be a wall between fuel compartments which consists of one 0.31" thick poison plate (the strength of the poison plates is neglected from the buckling load calculation, but the weight is included) sandwiched between two 0.135" thick stainless steel. The overall dimensions of this outer basket wall are 6.135" high and 6.0" wide. It is assumed that the load due to eight fuel assemblies stacked on 0.135" thick boxes is more severe than the weight of six fuel assemblies on 0.12" thick boxes. The maximum basket plate temperatures at locations 1 and 2 (Figure K.3.7-36) are 540°F, and 617°F respectively. The buckling analysis of the basket is conservatively performed at temperatures of 550°F for location 1 and 650°F for location 2.

Finite Element Model

A three-dimensional ANSYS finite element model is constructed using a Shell 43 plastic large strain shell element to evaluate the plastic buckling loads for the basket plates at locations 1 and 2 (Figure K.3.7-36). Shell 43 is well suited to model nonlinear, flat or warped, thin to moderately thick shell structures. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes. The nodes of various plates are coupled together in the out of plane direction so that they will bend in unison under surface pressure loading and to simulate the through thickness support provided by the poison plates. The finite element model simulation is shown on Figure K.3.7-37.

Geometric Nonlinearities

Since the structure experiences large deformations before buckling, the large displacement option of ANSYS is used. The deflections during each load step are used to continuously redefine the geometry of the structure, thus producing a revised stiffness matrix. If the rate of change in deflection (per iteration) is observed, an estimation of the stability of the structure can be made. In particular, if the change of displacement at any node is increasing, the loading is above critical and the structure will eventually buckle.

Material Nonlinearities

The basket is constructed from Type 304 stainless steel. A bilinear stress strain relationship is used to simulate the correct nonlinear material behavior. The elastic and inelastic material properties used in the analysis, are presented in Table K.3.7-7.

Loadings

The loadings on the panel model (Figure K.3.7-36, Locations 1 & 2) were appropriately transferred from full size basket loadings. The three critical drop orientations analyzed for basket plates at both locations are the following:

- Vertical (load applied in the direction parallel to the basket plates)
- 30° (load applied at 30° relative to the basket plate direction)
- 45° (load applied at 45° relative to the basket plate direction)

The loads used in vertical, 30, and 45 degree drop analyses are summarized in Table 3.7-8. Maximum loads of 200g were applied in each analysis. The automatic time stepping program option "Autots" was activated. This option lets the program decide the actual size of the load-substep for a converged solution. The program stops at the load substep when it fails to result in a converged solution. The last load step, with a converged solution, is the plastic instability load for the model. Figures K.3.7-37 shows the loading conditions.

Boundary Conditions

The ANSYS finite element model conservatively assumes that both ends of column are hinged. However, the stainless steel (0.135" thick) and poison plates forming the panel extend beyond the panel and connect into other panels so that moments can be developed at the top and bottom panel edges. These reactive end moments will keep the ends from rotating during buckling. "Formulas for Stress and Strain" by Raymond Roark [3.12], Fourth Edition, Table XV indicates that:

Load Case No. (From Table XV of Roark)	Loading and Edge Condition	Formula for Critical Load (P)
2	End Load Both Ends Hinged	$P = (1)(\pi^2 EI/L^2)$
3	End Load Both Ends Fixed	$P = (4)(\pi^2 EI/L^2)$

Based on the formulas described above, the end conditions selected for the ANSYS model (both ends hinged) are conservative and the calculated allowable compressive load has a large margin of safety.

ANSYS Finite Element Analysis Results

For each orientation, the analysis is solved with successfully higher loading until convergence can no longer be obtained from the FEA model. Stress intensities and displacement patterns, at the last converged substep, are shown on Figures K.3.7-38 to K.3.7-43.

As per paragraph F-1340 [3.1], the acceptability of a component may be demonstrated by collapse load analysis. The allowable collapse load shall not exceed 100% of the plastic analysis collapse load (F-1341.3). The plastic analysis collapse load is defined as that determined by plastic analysis according to the criteria given in II-1430 (F-1321.6(c)).

Using the methodology described in II-1430 (F-1321.6(c)). For each solution step, the maximum displacements are used to determine the collapse load (see Figures K.3.7-44 through K.3.7-49). Table K.3.7-9 summarizes the allowable buckling loads for each of the drop orientations. The analyses concludes that the maximum allowable buckling load is 96g's, which occurs for the 30° drop case.

K.3.7.5.3.3.2 Fuel Compartment Stability Demonstration Using Hand Calculations

As an order of magnitude check, the NUHOMS®-61BT basket plate allowable buckling load and interaction equations of paragraph NF-3322.1 (e) [3.1] are evaluated for the 75g side drop. The basket plates are evaluated at vertical and 30° drop orientations, at a temperature of 550°F, on the most critically loaded panel (Location 1, Figure K.3.7-36).

Vertical Drop (load applied in the direction parallel to the basket plate)

According to ASME Code, Subsection NF, Paragraph NF-3322-1(c)(2)(a)(Level A Condition) and modified as per Appendix F, Paragraph F-1334 (Level D Condition), the compressive stress limit under accident conditions (Level D) when KL/r is less than 120 and $S_u > 1.2\, S_y$ is:

$$F_a = 2 \times S_y\, [0.47 - (KL/r)/444]$$

Where:

$K = 0.65$ as recommended by AISC [3.18] (Table C1.8.1). Since the plate is continuously supported, the column is assumed to have fixed ends.
Plate height, $L = 6.0"$
Plate width, $b = 6.0"$
$E = 25.55 \times 10^6$ psi.
$S_y = 18.8$ ksi.
Moment of inertia, $I = b\,h^3/12 = 6 \times (0.58^3 - 0.31^3) / 12 = 0.0827$ in.^{4}
Area, $A = 6{\times}2{\times}0.135 = 1.62$ in.^{2}
$r = (I/A)^{1/2} = 0.2259$ in.
$KL/r = 0.65 \times 6.0 / 0.2259 = 17.26$

Substituting the values given above, the compressive stress limit, F_a, is,

$$F_a = 2 \times 18{,}800\ [0.47 - (17.26)/444] = 16{,}210 \text{ psi}$$

Total weight above bottom panel = 290 lbs.
Therefore, compressive stress at 75g, $f_a = 290 \times 75 / 1.62 = 13{,}426$ psi

For combined axial compression and bending, equations 20 and 21 of Paragraph NF-3322.1 (e) (1) are:

$$f_a/F_a + C_{mx}\, f_b / [1-(f_a/F_e)]\, F_b \le 1 \qquad \text{(Eq.20)}$$

$$f_a/(1.4)(0.6)S_y + f_b / F_b \le 1 \qquad \text{(Eq.21)}$$

The allowable stresses for the above equations are determined as follows:

	Allowable Stress	ASME Reference
F_b	$1.5\ S_y = 28{,}200$ psi	F-1334.5(c)
C_{mx}	0.6	NF 3322.1(e)(1)(b)
Note	The allowable stress F_a is multiplied by 1.4 as allowed by Paragraph F-1334	

Since there is no column bending during the vertical drop, the interaction equations are reduced to:

Equation 20: $f_a/F_a = 13{,}426/16{,}210 = 0.83 \le 1$

Equation 21: $f_a/(1.4)(0.6)S_y = 13{,}426/(1.4)(0.6)28{,}200 = 0.57 \leq 1$

30° Drop (load applied at 30° relative to the basket plate direction)

The plate span is treated as a beam-column with fixed ends under axial compression and uniform transverse load ("Formulas for Stress and Strain", Ed. 4, Table VI, Case 10 [3.12]).

During a 30 degree side drop,

Axial load (75g), $P = 75g \times 290 \cos(30) = 18{,}836$ lb.
Transverse pressure load (75g) = $75g \times 0.8 \sin(30) = 30$ psi.
The distributed transverse load, $w = 30$ psi $\times$ 6.0 in. = 360 lb./in

Moment at beam center,

$$M = wj^2\left[\frac{U/2}{\sin(U/2)} - 1\right]$$

Where,

$$j = \left[\frac{EI}{P}\right]^{1/2} = \left[\frac{(25.55\times10^6)(0.0827)}{118{,}836}\right]^{1/2} = 10.59$$

$$U = \frac{L}{j} = \frac{6.0}{10.59} = 0.567 \text{ rad.} = 32.49°$$

$$M = (360)(10.59^2)\left[\frac{0.569/2}{\sin(32.49/2)} - 1\right] = 542 \text{ in. lb.}$$

Bending stress, $f_b = Mc/I = 542 \times 0.29 / (0.0827) = 1{,}901$ psi.
Axial compressive stress, $f_a = P/A = 18{,}836/1.62 = 11{,}627$ psi.
$C_{mx} = 0.6$ [Ref. 3.2, Appendix F, F-1334.5(c)]
$F_b = 1.5\ S_y = 1.5 \times 18{,}800 = 28{,}200$ psi. (Subsection NF, NF 322.1(e)(1)(b))
The value of F_e is calculated by the formula below per Paragraph F-1334.5(b):

$$F_e = \frac{\pi^2 E}{1.30\left(\frac{kl}{r}\right)^2} = \frac{\pi^2 25\ 55\times10^6}{1.30(17.26)^2} = 651{,}127 \text{ psi.}$$

Eq.20: $$\frac{f_a}{F_a} + \frac{C_{mx} f_b}{(1 - f_b/F_e)F_b} = \frac{11{,}627}{16{,}210} + \frac{0.6(1{,}901)}{(1 - 1{,}901/651{,}127)28{,}200} = 0.76 \leq 1$$

Eq. 21: $$\frac{f_a}{(1.4)(0.6)S_y} + \frac{f_b}{F_b} = \frac{11{,}627}{(1.4)(0.6)18{,}800} + \frac{1{,}901}{28{,}200} = 0.8 \leq 1$$

The results of the hand analytical calculations confirm that allowable buckling loads in the basket plates due to a 75G side drop are within acceptable limits.

K.3.7.5.3.3.3 Support Rail Buckling Analysis

There are two types of rails (type 1 & type 2 – see Drawing NUH-61B-1064). The type 2 rail is shorter while the type 1 rail has longer vertical panels. Consequently, the type 1 rail is limiting for buckling. The overall position of this rail and its loading, with respect to the full basket model, are shown in Figure K.3.7-50.

A nonlinear stress analysis was conducted to evaluate the plastic buckling loads for the rail. The ANSYS computer code was utilized in this analysis. A three-dimensional finite element model of the rail was extracted from the full basket model as described in Section K.3.6.1.3.1. The finite element model of rail and displacement boundary conditions are shown in Figure K.3.7-51. The rail is constructed from SA-240, Type 304 stainless steel and its material properties at 500° F are as follows:

Material Properties (500°F)

Stainless Steel (SA-240 Type 304)

$E = 25.8 \times 10^6$ psi.
$S_y = 19.4$ ksi.
$S_u = 63.4$ ksi.
Tangent Modulus, $E_T = 5\%$ of E $= 1.29 \times 10^6$ psi.

Applied Loads Calculations

Vertical Load due to weight on top compartments:
(All weights are calculated for a 3 in. basket length)

- W, 14 fuel assemblies = 180.55 lb.
- W, 8 SS compartment tubes, 0.12" wall = 20.45 lb.
- W, 6 SS compartment tubes, 0.135" wall = 17.29 lb.
- W, 2 × 2 outer wrapper, 0.105" wall = 4.71 lb.
- W, 3 × 3 outer wrapper, 0.105" wall = 4.13 lb.
- W , poison plates = 17.72 lb.
- W, Rail = 8 lbs.

Total weight = 252.85 say 265 lb.

For 200g, total vertical Load = $265 \times 200 = 53{,}000$ lb.

Nonlinear ANSYS runs were made for two different load cases:

In the first case: 53,000 lb. load was applied equally at six nodal locations on the rail (8,833.33 lbs at each node, see Figure K.3.7-51). Stress intensities and displacement patterns, at the last converged substep (131.5g), are shown in Figure K.3.7-52.

In the second case: 53,000 lb load was applied using a 2:1 ratio for two middle nodal and four end nodal locations (13,250 lbs at each middle node and 6,625 at each end node, see Figure K.3.7-51). Stress intensity and displacement patterns, at the last converged substep (160g), are shown in Figure K.3.7-53. Thus this load case is not bounding.

Using the methodology described earlier for the basket model, the allowable collapse loads have been determined for the first load case in Figure K.3.7-54. The allowable collapse load for the rail is 128g. For other rails and loadings, the allowable collapse load will be higher.

K.3.7.5.3.3.4 Results of Basket Buckling Analysis

The results of the analysis indicate the allowable collapse g loads for the NUHOMS®-61BT basket are higher than the applied 75g side drop impact load. It is seen that the lowest allowable (96 g) collapse load occurs during a 30° drop at basket location 1. The allowable collapse load for the rail is determined to be 128g. Thus the basket and rails will not buckle during the side drop event.

K.3.7.5.4 On-site Transfer Cask Horizontal and Vertical Drop Evaluation

An analysis has been performed [Section 8.2.5.2 of the CSAR] to evaluate the transfer cask when loaded with the NUHOMS®-52B DSC for postulated horizontal and vertical drop accidents with a static equivalent deceleration of 75g's.

The weight of the NUHOMS®-61BT DSC is 88,390 lbs compared to the 80,000 lbs used for the NUHOMS®-52B DSC. The minimum margin of safety for the NUHOMS®-52B DSC analysis for this accident has been scaled by a factor of [80,000/88390 = 0.905] to establish the minimum factor of safety applicable to the NUHOMS®-61BT DSC. See Section K.3.7.10.3.

K.3.7.5.4.1 On-site Transfer Cask Vertical Drop Analysis

This analysis has been described in Section 8.2.5.2 D of the CSAR when the Transfer Cask is loaded with NUHOMS®-52B DSC.

The weight of the NUHOMS®-61BT DSC is 88,390 lbs compared to 80,000 lbs for the NUHOMS®-52B DSC. The minimum margin of safety for the NUHOMS®-52B DSC analysis for this accident has been scaled by a factor of [80,000/88,390 = 0.905] to establish the minimum factor of safety applicable to the NUHOMS®-61BT DSC. See Section K.3.7.10.3.

K.3.7.5.5 Loss of Neutron Shield

No impact on Structural Evaluation in the CSAR.

K.3.7.6 Lightning

No impact on Structural Evaluation in the CSAR.

K.3.7.7 Blockage of Air Inlet and Outlet Openings

This accident conservatively postulates the complete blockage of the HSM ventilation air inlet and outlet openings on the HSM side walls.

Since the NUHOMS® HSMs are located outdoors, there is a remote probability that the ventilation air inlet and outlet openings could become blocked by debris from such unlikely events as floods and tornadoes. The NUHOMS® design features such as the perimeter security fence and the redundant protected location of the air inlet and outlet openings reduces the probability of occurrence of such an accident. Nevertheless, for this conservative generic analysis, such an accident is postulated to occur and is analyzed.

The structural consequences due to the weight of the debris blocking the air inlet and outlet openings are negligible and are bounded by the HSM loads induced for a postulated tornado (Section 8.2.2 of the CSAR) or earthquake (Section 8.2.3 of the CSAR).

The thermal effects of this accident for the NUHOMS®-61BT DSC are enveloped by the storage of 24P DSC which has a higher heat load of 24 kw as described in Section K4.0.

K.3.7.8 DSC Leakage

There are no structural or thermal consequences resulting from the DSC leakage accident. The radiological consequences of this accident are described in Section K.11.2.1.3.

K.3.7.9 Accident Pressurization of DSC

This accident addresses the consequences of accidental pressurization of the DSC.

See Section K.4.0 for this analysis.

K.3.7.10 Load Combinations

The load categories associated with normal operating conditions, off-normal conditions and postulated accident conditions are described and analyzed in previous sections. The load combination results for the NUHOMS® components important to safety are presented in this section. Fatigue effects on the transfer cask and the DSC are also addressed in this section.

K.3.7.10.1 DSC Load Combination Evaluation

As described in Section 3.2 of the CSAR, the stress intensities in the DSC at various critical locations for the appropriate normal operating condition loads are combined with the stress intensities experienced by the DSC during postulated accident conditions. It is assumed that only one postulated accident event occurs at any one time. The DSC load combinations summarized in Table 3.2-6 of the CSAR are expanded in Table K.3.7-15. Since the postulated cask drop accidents are by far the most critical, the load combinations for these events envelope all other accident event combinations. Table K.3.7-11 through Table K.3.7-13 tabulate the maximum stress intensity for each component of the DSC (shell and basket assemblies) calculated for the enveloping normal operating, off-normal, and accident load combinations. For comparison, the appropriate ASME Code allowables are also presented in these tables.

K.3.7.10.2 DSC Fatigue Evaluation

Although the normal and off-normal internal pressures for the NUHOMS®-61BT DSC are slightly higher relative to the NUHOMS®-52B DSC, the range of pressure fluctuations due to seasonal temperature changes are essentially the same as those evaluated for the NUHOMS®-52B DSC. Similarly, the normal and off-normal temperature fluctuations for the NUHOMS®-61BT DSC due to seasonal fluctuations are essentially the same as those calculated for the NUHOMS®-52B DSC. Therefore, the fatigue evaluation presented in Section 8.2.10.2 of the CSAR remains applicable to the NUHOMS®-61BT DSC.

K.3.7.10.3 Transfer Cask Load Combination Evaluation

As described in Section 3.2 of the CSAR, the transfer cask calculated stresses due to normal operating loads are combined with the appropriate calculated stresses from postulated accident conditions at critical stress locations. It is assumed that only one postulated accident can occur at a time. Also, since the postulated drop accidents produce the highest calculated stresses, the load combination of dead load plus drop accident envelopes the stresses induced by other postulated accident scenarios. The limiting (minimum) factor of safety for membrane plus bending stress intensity in the Cask Bottom Support Ring under the dead weight plus thermal plus earthquake load combination has been updated to reflect the increased deadweight of 88,390 lbs for the NUHOMS®-61BT DSC. This updated limiting factor of safety is conservatively established as 1.22. Hence, the resulting stresses for the OS 197 Transfer Cask when handling the NUHOMS®-61BT DSC remain well below the code allowables

K.3.7.10.4 Transfer Cask Fatigue Evaluation

No Change to the evaluation presented in the CSAR.

K.3.7.10.5 HSM Load Combination Evaluation

The existing HSM structural qualification evaluations provided in Sections 8.1 and 8.2 of the CSAR include a NUHOMS® DSC weight 80,000 lbs used for the NUHOMS®-52B DSC. The weight of the NUHOMS®-61BT DSC (88,390 lbs) is approximately 11% greater than 80,000 lbs. The effects of the increased weight and corresponding frequency shifts are evaluated by scaling the NUHOMS®-52B governing load case stress ratios (or demand/capacity ratios) that are affected by the weight and acceleration increases to ensure that ratios are less than 1.0. A comparison of the weights of the NUHOMS®-61BT DSC and an HSM loaded with the NUHOMS®-61BT DSC to the corresponding values for the NUHOMS®-52B DSC/HSM and the maximum acceleration ratio for a 5% frequency shift is shown in Table K.3.7-10.

Table K.3.7-2 shows that all the limiting HSM structural components are acceptable using a conservative scaling factor of 1.11 for deadweight and 1.14 for seismic.

K.3.7.10.6 Thermal Cycling of the HSM

No Change to the evaluation presented in the CSAR.

K.3.7.10.7 DSC Support Structure Load Combination Evaluation

See Section K.3.7.10.5 above.

Table K.3.7-1
Postulated Accident Loading Identification

Accident Load Type	Section Reference	NUHOMS® Component Affected				
		DSC Shell Assembly	DSC Basket	DSC Support Structure	HSM	On-Site Transfer Cask
Loss of Adjacent HSM Shielding Effects	8.2.1	(radiological consequence only)				
Tornado Wind	8.2.2				X	X
Tornado Missiles	8.2.2				X	X
Earthquake	8.2.3	X	X	X	X	X
Flood	8.2.4	X			X	
Accident Cask Drop	8.2.5	X	X			X
Loss of Cask Neutron Shield	8.2.5					X
Lightning	8.2.6				X	
Blockage of HSM Air Inlets and Outlets	8.2.7	X	X	X	X	
DSC Leakage	8.2.8	(radiological consequence only)				
DSC Accident Internal Pressure	8.2.9	X				
Load Combinations	8.2.10	X	X	X	X	X

Table K.3.7-2
HSM Limiting Component Evaluation – NUHOMS®-61BT vs. -52B

Component	Stress Ratio (or Demand/Capacity) [1]		
	52B	61BT[3]	Status
HSM Concrete Floor	0.71	0.81	Acceptable
HSM Concrete Side Wall	0.69	0.79	Acceptable
HSM Concrete Front Wall	0.94	1.07	Further evaluation gives a ratio of 0.94[2]
DSC Steel Support Column	0.80	0.91	Acceptable
DSC Steel Support Wall Attachment Bolt	0.74	0.84	Acceptable
DSC Steel Support Rail Extension Plates	0.93	1.06	Further evaluation gives a ratio of 0.94[2]
DSC Steel Support Rail Stiffener Weld	0.86	0.98	Acceptable
DSC Steel Support Stop Plate Stiffener Weld	0.86	0.98	Acceptable
DSC Steel Support Beam Flange to Stiffener Weld	0.89	1.01	Further evaluation gives a ratio of 0.98[2]
HSM Concrete Floor Embedment	0.76	0.87	Acceptable

Notes:
1. Accident thermal and HSM binding load conditions/combinations are not included because the DSC weight has essentially no effect on these results.
2. The stress ratio is governed by thermal loading for these components. The scaling of the deadweight effects by a factor of 1.11 and seismic effects by a factor of 1.14 results in a negligible or small increase in the combined stress ratio.
3. Values are conservatively based on a factor of 1.14 times the NUHOMS®-52B stress ratios.

Table K.3.7-3
Maximum NUHOMS®-61BT DSC Stresses for Drop Accident Loads(2)

DSC Components	Stress Type	Calculated Stress (ksi)(1)	
		Vertical	Horizontal
DSC Shell	Primary Membrane	11.93	35.85
	Membrane + Bending	31.78	58.98
Inner Top Cover Plate	Primary Membrane	1.70	32.34
	Membrane + Bending	1.90	55.21
Outer Top Cover Plate	Primary Membrane	1.70	39.84
	Membrane + Bending	2.25	54.89
Inner Bottom Cover Plate	Primary Membrane	6.37	22.80
	Membrane + Bending	23.78	56.77
Outer Bottom Cover Plate	Primary Membrane	1.70	32.39
	Membrane + Bending	3.07	47.04
Top Cover Plate Weld(2)	Primary	0.95	21.11
Bottom Cover Plate Weld	Primary	0.67	9.13

Notes:
(1) Values shown are maximums irrespective of location.
(2) Stress values are the envelope of drop loads with and without 20psig internal pressure.

Table K.3.7-4
Fuel Assembly Weight Simulation Based on 1g Load

Drop Orientations	Pressure Applied to Horizontal Plates $P \times \sin\theta$ (psi)	Pressure Applied to Vertical Plates $P \times \cos\theta$ (psi)
90° and 180°	0.6911	-
45°	0.4887	0.4887
60°	0.5985	0.3456
161.5°	0.6554	0.2193

Table K.3.7-5
Stress Summary of the Basket Due to Side Drop Loads – 75G

Drop Orientation	Component	Stress Category	Max. Stress (ksi)	Allowable Stress (ksi)[1]	Reference Figures
45° Side Drop	Basket	P_m	14.54	44.38	Figure K.3.7-6
		$P_m + P_b$	27.12	57.06	Figure K.3.7-7
	Rails	P_m	16.52	44.38	Figure K.3.7-8
		$P_m + P_b$	25.27	57.06	Figure K.3.7-9
	Canister	P_m	2.01	44.38	Figure K.3.7-10
		$P_m + P_b$	19.60	57.06	Figure K.3.7-11
60° Side Drop	Basket	P_m	14.43	44.38	Figure K.3.7-12
		$P_m + P_b$	27.30	57.06	Figure K.3.7-13
	Rails	P_m	20.85	44.38	Figure K.3.7-14
		$P_m + P_b$	28.72	57.06	Figure K.3.7-15
	Canister	P_m	2.44	44.38	Figure K.3.7-16
		$P_m + P_b$	19.57	57.06	Figure K.3.7-17
90° Side Drop	Basket	P_m	18.02	44.38	Figure K.3.7-18
		$P_m + P_b$	22.78	57.06	Figure K.3.7-19
	Rails	P_m	29.03	44.38	Figure K.3.7-20
		$P_m + P_b$	32.79	57.06	Figure K.3.7-21
	Canister	P_m	3.17	44.38	Figure K.3.7-22
		$P_m + P_b$	16.83	57.06	Figure K.3.7-23
	Rail Weld Stud	Shear	17.43	26.63	--
161.5° Side Drop Impact on one Transfer cask Support rail	Basket	P_m	13.47	44.38	Figure K.3.7-24
		$P_m + P_b$	25.76	57.06	Figure K.3.7-25
	Rails	P_m	19.71	44.38	Figure K.3.7-26
		$P_m + P_b$	44.37	57.06	Figure K.3.7-27
	Canister	P_m	3.27	44.38	Figure K.3.7-28
		$P_m + P_b$	23.12	57.06	Figure K.3.7-29
180° Side Drop Impact on two Transfer cask Support rails	Basket	P_m	16.22	44.38	Figure K.3.7-30
		$P_m + P_b$	23.55	57.06	Figure K.3.7-31
	Rails	P_m	28.09	44.38	Figure K.3.7-32
		$P_m + P_b$	34.71	57.06	Figure K.3.7-33
	Canister	P_m	4.72	44.38	Figure K.3.7-34
		$P_m + P_b$	26.13	57.06	Figure K.3.7-35

(1) Allowables are taken at a temperature of 650°F

Table K.3.7-6
Stress Summary of the Basket due to 75g End Drop Load

Drop Orientation	Component	Stress Category	Max. Stress (ksi)	AllowableStress (ksi)[1]
End Drop	Hold down Ring	P_m	7.5	44.45
End Drop	Basket	P_m	6.75	44.45
	Rail weld Stud	Shear	9.75	26.7
	Plate Insert Weld	Shear	13.35	26.7

[1] Allowable stresses are determined at 650°F.

Table K.3.7-7
Mechanical Properties of SA-240 Type 304 SS

	550°F	650°F
Modulus of Elasticity (psi)	25.55×10^6	25.05×10^6
Yield Strength (psi)	18,900	18,000
Ultimate Strength (psi)	63,400	63,400
Tangent Modulus (psi)	1.2775×10^6	1.2525×10^6

Table K.3.7-8
Summary of Loads Used for Different Drop Orientations

Location 1
($F_y = F \cos\theta$, $P_x = P \sin\theta$, F = 290 lbs, P = 0.8 psi)

Drop Orientation (Degree)	1G load (6" Length) (Weight including all SS & poison plates above the bottom panel, rails, and 8 fuel assemblies**)		200 G Load Computer Run	
	Axial Load F_y (lbs)	Trans. Load P_x (psi)	F_y (lbs)	P_x(psi)
Vertical	290	0	58,000	0
30	251	0.4	50,200	80
45	205	0.565	41,000	113

** This assumption is very conservative for drop orientations other than the vertical drop. For example, for 30 and 45 degree drops, the bottom panel only supports 6 fuel assemblies but was analyzed for 8 fuel assemblies.

Location 2
($F_y = F \cos\theta$, $P_x = P \sin\theta$, F = 160 lbs, P = 0.8 psi)

Drop Orientation (Degree)	1G load (6" Length) (Weight including all SS & poison plates above the bottom panel, rails, and 4 fuel assemblies**)		200 G Load Computer Run	
	Axial Load F_y (lbs)	Trans. Load P_x (psi)	F_y (lbs)	P_x(psi)
Vertical	160	0	32,000	0
30	139	0.4	27,800	80
45	113	0.565	22,600	113

** This assumption is also very conservative for drop orientations other than vertical drop. For example, for 30 and 45 degree drops, the bottom panel only supports 3 fuel assemblies but was analyzed for 4 fuel assemblies.

Table K.3.7-9
Summary of Basket Buckling Analysis

Location 1
(550°F)

Basket Orientation	Last Converged Load (g)	Allowable Collapse Load	Reference Figure
Vertical	112	112	K.3.7-44
30°	99	96	K.3.7-45
45°	105	100	K.3.7-46

Location 2
(650°F)

Basket Orientation	Last Converged Load (g)	Allowable Collapse Load	Reference Figure
Vertical	187	185	K.3.7-47
30°	148	139	K.3.7-48
45°	146	140	K.3.7-49

Table K.3.7-10
Weight Comparison – NUHOMS®-61BT vs. -52B

	NUHOMS ®-52B	NUHOMS® -61BT	Ratio	Acceleration Scale Factor(1)	Total Scale Factor
DSC Weight	80 kips	88.4 kips	1.105	1.032	1.14
HSM Weight	252 kips	252 kips	---		---
DSC + HSM Weight	332 kips	340.4 kips	1.025		1.06

Note:

1. A 5% frequency shift at 33 Hz due to the weight increase results in an acceleration increase from 0.250g to 0.258g which results in a ratio of 1.032.

Table K.3.7-11
NUHOMS®-61BT DSC Enveloping Load Combination Results for Normal and Off-Normal Loads
(ASME Service Levels A and B)

DSC Components	Stress Type	Controlling Load Combination (1)	Stress (ksi)	
			Calculated	Allowable (2)
DSC Shell	Primary Membrane	TR-3, TR-7	7.17	17.5
	Membrane + Bending	N0-1	19.39	40.5
	Primary + Secondary	LD-4	53.69	54.3
Inner Bottom Cover Plate	Primary Membrane	LD-4	4.71	17.5
	Membrane + Bending	N0-1	18.84	40.5
	Primary + Secondary	LD-4	37.71	54.3
Outer Bottom Cover Plate	Primary Membrane	LD-4, LD-5	6.28	17.5
	Membrane + Bending	UL-4,UL-5, UL-6	25.44	29.0
	Primary + Secondary	UL-5	34.68	58.0
Inner Top Cover Plate	Primary Membrane	TR-5	3.75	17.5
	Membrane + Bending	HSM-4	10.69	28.1
	Primary + Secondary	TR-1, TR-5	33.35	52.5
Outer Top Cover Plate	Primary Membrane	HSM-4	4.93	18.7
	Membrane + Bending	HSM-4	16.09	28.1
	Primary + Secondary	HSM-4	29.42	56.1
Basket	Primary Membrane	TR-8	0.8	16.2
	Membrane + Bending	TR-8	3.67	24.3
	Primary + Secondary	HSM-3	17.69	48.6
Rail	Primary Membrane	TR-8	1.18	16.2
	Membrane + Bending	TR-8	5.11	24.3
	Primary + Secondary	HSM-3	11.51	48.6
Rail Stud	Shear	DD-2	0.19	9.72

See Table K.3.7-14 for notes.

Table K.3.7-12
NUHOMS®-61BT DSC Enveloping Load Combination Results for Accident Loads

(ASME Service Level C)

DSC Components	Stress Type	Controlling Load Combination (1)	Stress (ksi)	
			Calculated	Allowable(2)
DSC Shell	Primary Membrane	HSM-8	16.85	22.4
	Membrane + Bending	HSM-8	25.71	33.7
Inner Bottom Cover Plate	Primary Membrane	HSM-8	9.71	23.2
	Membrane + Bending	HSM-8	16.36	34.8
Outer Bottom Cover Plate	Primary Membrane	UL-7	7.87	23.2
	Membrane + Bending	UL-7	33.01	34.8
Inner Top Cover Plate	Primary Membrane	HSM-8	8.61	22.4
	Membrane + Bending	HSM-8	21.37	33.7
Outer Top Cover Plate	Primary Membrane	HSM-8	8.06	22.4
	Membrane + Bending	HSM-8	21.78	33.7
Basket	Primary Membrane	HSM-8	1.46	16.2
	Membrane + Bending	HSM-8	5.62	24.3
Rail	Primary Membrane	HSM-8	1.76	16.2
	Membrane + Bending	HSM-8	10.6	24.3
Rail Stud	Shear	HSM-8	3.47	26.67

See Table K.3.7-14 for notes.

Table K.3.7-13
NUHOMS®-61BT DSC Enveloping Load Combination Results for Accident Loads
(ASME Service Level D) (3)

DSC Components	Stress Types	Controlling Load Combination (1)	Stress (ksi)	
			Calculated	Allowable(2)
DSC Shell	Primary Membrane	TR-10	35.85	44.4
	Membrane + Bending	TR-10	58.98	62.2(5)
Inner Bottom Cover Plate	Primary Membrane	TR-10	22.80	44.4
	Membrane + Bending	TR-10	56.77	59.6(6)
Outer Bottom Cover Plate	Primary Membrane	TR-10	32.39	44.4
	Membrane + Bending	UL-8	62.54	65.1
Inner Top Cover Plate	Primary Membrane	TR-10	32.34	44.4
	Membrane + Bending	TR-10	55.21	57.1
Outer Top Cover Plate	Primary Membrane	TR-10	39.84	44.4
	Membrane + Bending	TR-10	54.89	57.1
Basket	Primary Membrane	TR-10	18.02	44.38
	Membrane + Bending	TR-10	27.30	57.06
Rail	Primary Membrane Membrane + Bending	TR-10 TR-10	29.03 44.37	44.38 57.06
Rail Stud	Shear	TR10	17.43	26.63

See Table K.3.7-14 for notes.

Table K.3.7-14
DSC Enveloping Load Combination Table Notes

(1) See Table K.3.2-6 for load combination nomenclature.

(2) See Table K.3.2-9 for allowable stress criteria. Material properties were obtained from Table 8.1-3 of CSAR at a design temperature of 500°F or as noted.

(3) In accordance with the ASME Code, thermal stresses need not be included in Service Level D load combinations.

(4) Evaluated per ASME NB-3228.5 for components with stresses greater than $3.0S_m$.

(5) The maximum side drop membrane + bending stress is highly localized near the cask rail, at the outer bottom cover plate. The maximum temperature in this region is less than 240°F (temperature case 2).

(6) The maximum side drop membrane + bending stress is highly localized over the cask rail. The maximum temperature in this region is less than 300°F (temperature case2).

Table K.3.7-15
Summary of DSC Load Combinations

	Horiz. DW		Vertical DW		Internal Pressure [8]	External Pressure	Thermal Condition	Lifting Loads	Other Loads	Service Level
	DSC	Fuel	DSC	Fuel						
NON-OPERATIONAL LOAD COMBINATIONS										
NO-1 Fab. Leak Testing	--	--	--	--	--	14.7 psi	70°F	--	155 kip axial	Test
NO-2 Fab. Leak Testing	--	--	--	--	12 psi	--	70°F	--	155 kip axial	Test
NO-3 DSC Uprighting	X	--	--	--	--	--	70°F	X	--	A
NO-4 DSC Vertical Lift	--	--	X	--	--	--	70°F	X	--	A
FUEL LOADING LOAD COMB.										
FL-1 DSC/Cask Filling	--	--	Cask	--	--	Hydrostatic	100°F Cask	x	x	A
FL-2 DSC/Cask Filling	--	--	Cask	--	Hydrostatic	Hydrostatic	100°F Cask	x	x	A
FL-3 DSC/Cask Xfer	--	--	Cask	--	Hydrostatic	Hydrostatic	100°F Cask	--	--	A
FL-4 Fuel Loading	--	--	Cask	X	Hydrostatic	Hydrostatic	100°F Cask	--	--	A
FL-5 Xfer to Decon	--	--	Cask	X	Hydrostatic	Hydrostatic	100°F Cask	--	--	A
FL-6 Inner Cover Plate Welding	--	--	Cask	X	Hydrostatic	Hydrostatic	100°F Cask	--	--	A
FL-7 Fuel Deck Seismic Loading	--	--	Cask	X	Hydrostatic	Hydrostatic	100°F Cask	--	Note 9	C
DRAINING AND DRYING LOAD COMBINATIONS										
DD-1 DSC Blowdown	--	--	Cask	X	Hydrostatic + 20 psi	Hydrostatic	100°F Cask	--	--	A
DD-2 Vacuum Drying	--	--	Cask	X	0 psia	Hydrostatic + 14.7 psi	100°F Cask	--	--	A
DD-3 Helium Backfill	--	--	Cask	X	12 psi	Hydrostatic	100°F Cask	--	--	A
DD-4 Final Helium Backfill	--	--	Cask	X	3.5 psi	Hydrostatic	100°F Cask	--	--	A
DD-5 Outer Cover Plate Welding	--	--	Cask	X	3.5 psi	Hydrostatic	100°F Cask	--	--	A
TRANSFER TRAILER LOADS										
TL-1 Vertical Xfer to Trailer	--	--	Cask	X	10.0 psi	--	0°F Cask	--	--	A
TL-2 "	--	--	Cask	X	10.0 psi	--	100°F Cask	--	--	A
TL-3 Laydown	Cask	X	--	--	10.0 psi	--	0°F Cask	--	--	A
TL-4 "	Cask	X	--	--	10.0 psi	--	100°F Cask	--	--	A

	Horiz. DW		Vertical DW		Internal Pressure [8]	External Pressure	Thermal Condition	Handling Loads	Other Loads	Service Level
	DSC	Fuel	DSC	Fuel						
TRANSFER TO / FROM ISFSI										
TR-1 Axial Load - Cold	Cask	X	--	--	10.0 psi	--	0°F Cask	1g Axial	--	A
TR-2 Transverse Load - Cold	Cask	X	--	--	10.0 psi	--	0°F Cask	1g Transverse	--	A
TR-3 Vertical Load - Cold	Cask	X	--	--	10.0 psi	--	0°F Cask	1g Vertical	--	A
TR-4 Oblique Load - Cold	Cask	X	--	--	10.0 psi	--	0°F Cask	½g Axial + ½g Trans + ½g Vert	--	A
TR-5 Axial Load - Hot	Cask	X	--	--	10.0 psi	--	100°F Cask	1g Axial	--	A
TR-6 Transverse Load - Hot	Cask	X	--	--	10.0 psi	--	100°F Cask	1g Transverse	--	A
TR-7 Vertical Load - Hot	Cask	X	--	--	10.0 psi	--	100°F Cask	1g Vertical	--	A
TR-8 Oblique Load - Hot	Cask	X	--	--	10.0 psi	--	100°F Cask	½g Axial + ½g Trans + ½g Vert	--	A
TR-9 25g Corner Drop [10]	Note 1		Note 1		20.0 psi		100°F Cask[2]		25g CornerDrop	D
TR-10 75g Side Drop [10]	Note 1		--	--	20.0 psi	--	100°F Cask[2]	--	75g Side Drop	D
TR-11 75g End Drop [10]			Note 1		20.0 psi		100°F Cask[2]		25g End Drop	D

(continued on next page)

Table K.3.7-15
Summary of DSC Load Combinations

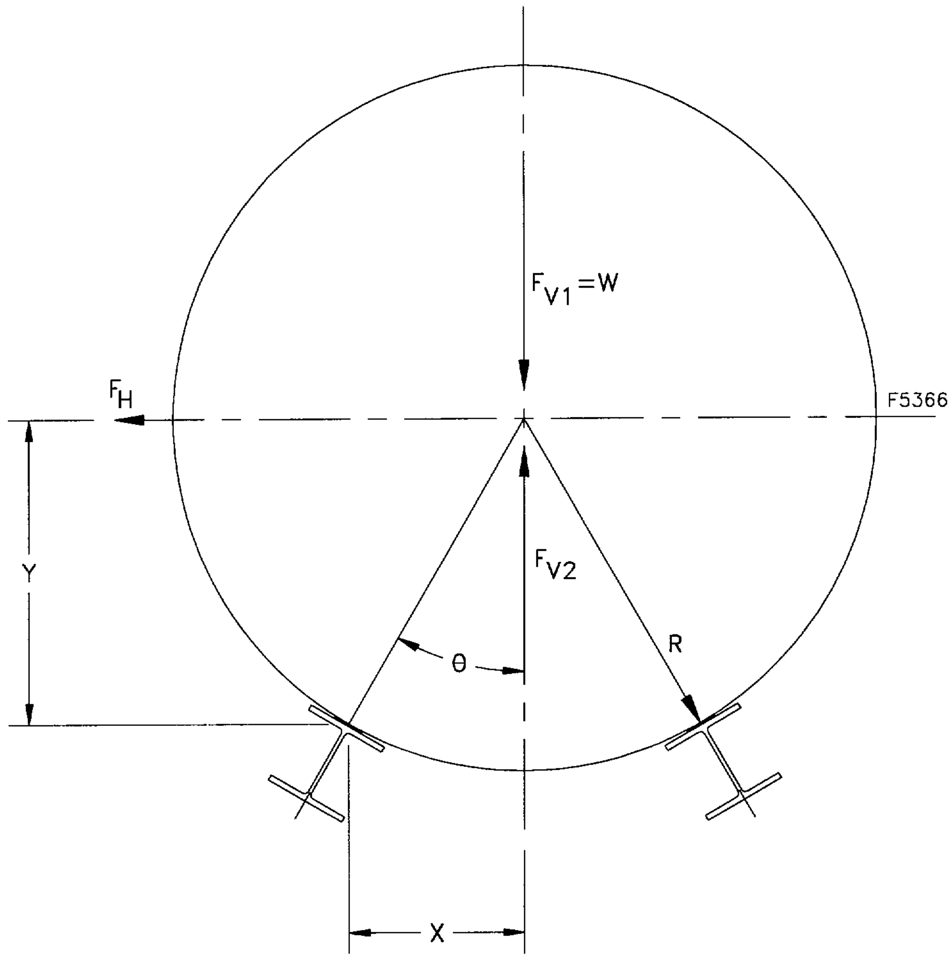
(continued)

	Horiz. DW		Vertical DW		Internal Pressure [8]	External Pressure	Thermal Condition	Handling Loads	Other Loads	Service Level
	DSC	Fuel	DSC	Fuel						
HSM LOADING										
LD-1 Normal Loading - Cold	Cask	X	--	--	10.0 psi	--	0°F Cask	+80 Kip	--	A
LD-2 Normal Loading - Hot	Cask	X	--	--	10.0 psi	--	100°F Cask	+80 Kip	--	A
LD-3 Normal Loading - Hot	Cask	X	--	--	10.0 psi	--	125°F w/shade[5]	+80 Kip	--	A
LD-4 Off-Normal Load - Cold	Cask	X	--	--	20.0 psi	--	0°F Cask	+80 Kip	Failed Fuel	B
LD-5 Off-Normal Load - Hot	Cask	X	--	--	20.0 psi	--	100°F Cask	+80 Kip	Failed Fuel	B
LD-6 Off-Normal Load - Hot	Cask	X	--	--	20.0 psi	--	125°F w/shade[5]	+80 Kip	Failed Fuel	B
LD-7 Accident Loading	Cask	X	--	--	20.0 psi	--	125°F w/shade[5]	+80 Kip	Failed Fuel	C/D
HSM STORAGE										
HSM-1 Off-Normal Storage	HSM	X	--	--	10.0 psi	--	-40°F HSM	--	--	B
HSM-2 Normal Storage	HSM	X	--	--	10.0 psi	--	0°F HSM	--	--	A
HSM-3 Off-Normal Storage	HSM	X	--	--	10.0 psi	--	125°F HSM	--	--	B
HSM-4 Off-Normal Temp. + Failed Fuel	HSM	X	--	--	20.0 psi	--	125°F HSM [2]	--	Failed Fuel	C
HSM-5 Blocked Vent Storage	HSM	X	--	--	65.0 psi [7]	--	125°F HSM / BV[2,4]	--	--	D
HSM-6 Blocked Vent + Failed Fuel Storage	HSM	X	--	--	65.0 psi [7]	--	125°F HSM / BV[2,4]	--	Failed Fuel	D
HSM-7 Earthquake Load - Cold	HSM	X	--	--	10.0 psi	--	0°F HSM [2]	--	Seismic	C
HSM-8 Earthquake Load - Hot	HSM	X	--	--	10.0 psi	--	100°F HSM [2]	--	Seismic	C
HSM-9 Flood Load (50' H_2O) - Cold	HSM	X	--	--	0.0 psi	22	0°F HSM [2]	--	Flood[3]	C
HSM10 Flood Load (50' H_2O) - Hot	HSM	X	--	--	0.0 psi	22	100°F HSM [2]	--	Flood[3]	C
HSM UNLOADING										
UL-1 Normal Unload - Cold	HSM	X	--	--	10.0 psi	--	0°F HSM	-60 Kip	--	A
UL-2 Normal Unload - Hot	HSM	X	--	--	10.0 psi	--	100°F HSM	-60 Kip	--	A
UL-3 Normal Unload - Hot	HSM	X	--	--	10.0 psi	--	125°F HSM	-60 Kip	--	A
UL-4 Off-Normal Unload - Cold	HSM	X	--	--	20.0 psi	--	0°F HSM	-60 Kip	--	B
UL-5 Off-Normal Unload - Hot	HSM	X	--	--	20.0 psi	--	100°F HSM	-60 Kip	--	B
UL-6 Off-Normal Unload - Hot	HSM	X	--	--	20.0 psi	--	125°F HSM	-60 Kip	--	B
UL-7 Off-Normal Unloading - FF/Hot[6]	HSM	X	--	--	21.0 psi	--	100°F HSM	-80 kip	--	C
UL-8 Off-Normal Unloading - FF/Hot[6]	HSM	X	--	--	65.0 psi[6,7]	--	100°F HSM	-80 kip	--	D
DSC UNLOADING/REFLOOD										
RF-1 DSC Reflood	--	--	Cask	X	20.0	Hydrostatic	100°F Cask	--	--	D

See following page for notes.

Notes to Table K.3.7-15:

1. 25g and 75g drop accelerations include gravity effects. Therefore, it is not necessary to add an additional 1.0g load.
2. For Level D events, only the maximum temperature case is considered. (Thermal stresses are not limited for Level D events and maximum temperatures give minimum allowables).
3. Flood load is an external pressure equivalent to 50 ft. of water.
4. BV = HSM Vents are blocked
5. At temperatures over 100°F, a sunshade is required over the Transfer Cask. Temperatures for these cases are enveloped by the 100°F (without sunshade) case.
6. As described in Section K.4 this pressure assumes release of the fuel cover gas and 30% of the fission gas. Although unloading requires the HSM door to be removed, the pressure and temperatures are based on the blocked vent condition. Pressure is applied to the outer pressure boundary.
7. This pressure is applied to the inner or outer pressure boundary.
8. Unless noted otherwise, pressure is applied to the inner pressure boundary
9. Fuel deck seismic loads are enveloped by handling loads.
10. The 75g top end drop and bottom end drop are not credible events. However, consideration of 75g end drops and a 75g side drop conservatively envelop the effects of a 25g corner drop.



WHERE:

R = 33.625 in., DSC outer radius

θ = 30°

X = R Sin θ = 16.8 in.

Y = R Cos θ = 29.1 in.

F_{V1} = W = weight of DSC

F_{V2} = W(0.17g) = upward vertical seismic load

F_H = W(0.37g) = horizontal seismic load

Figure K.3.7-1
DSC Lift-Off Evaluation

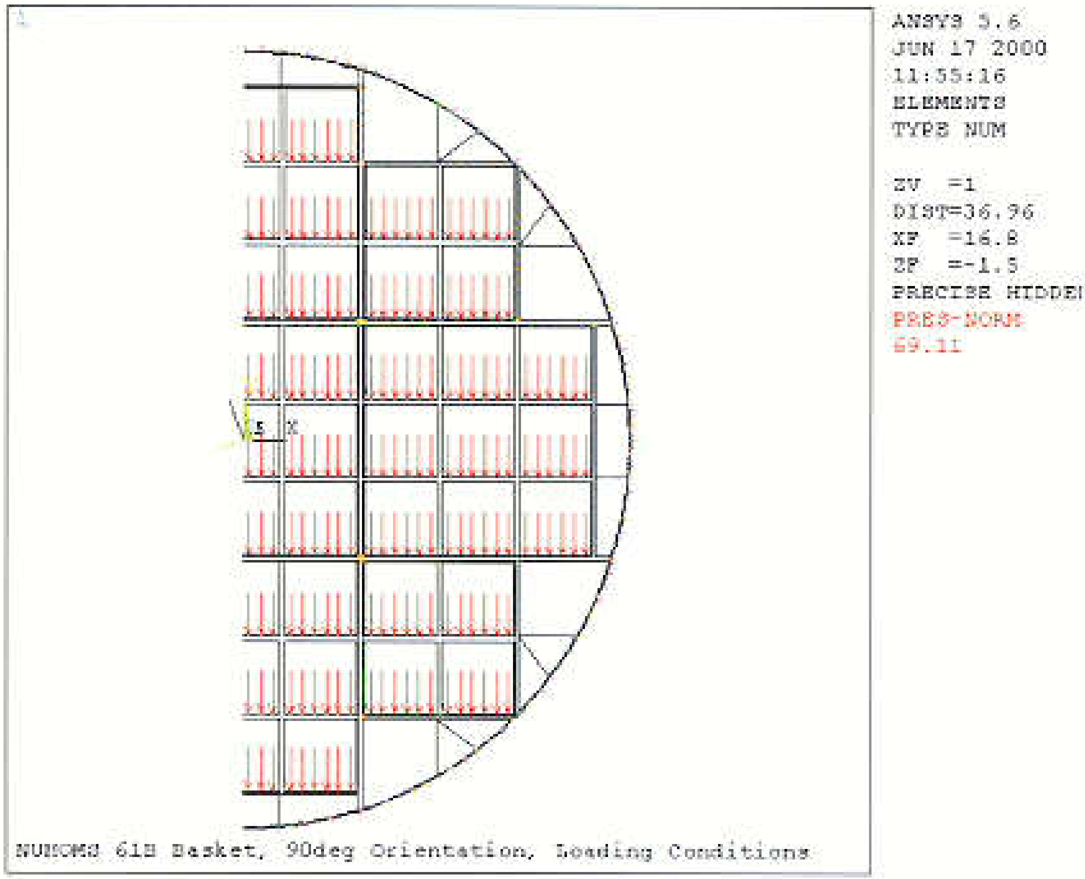


Figure K.3.7-2
90° and 180° Orientation Side Drop – Loading Conditions

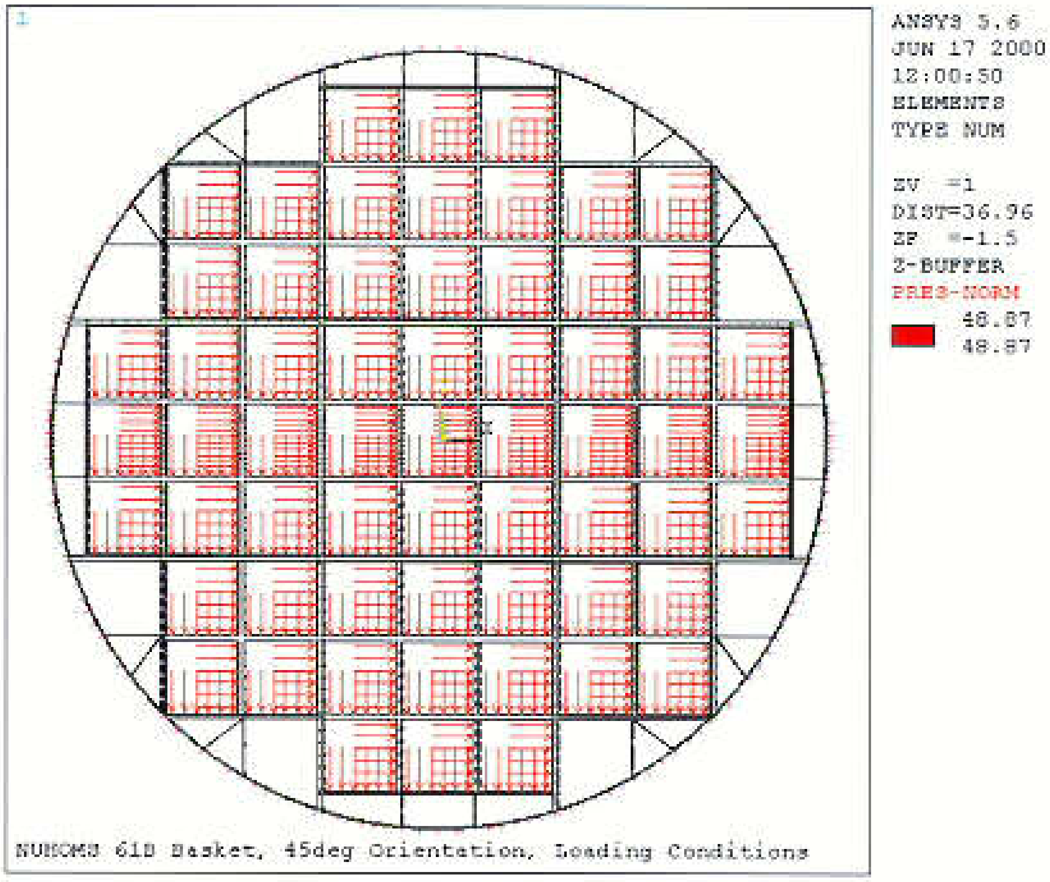


Figure K.3.7-3
45° Orientation Side Drop – Loading Conditions

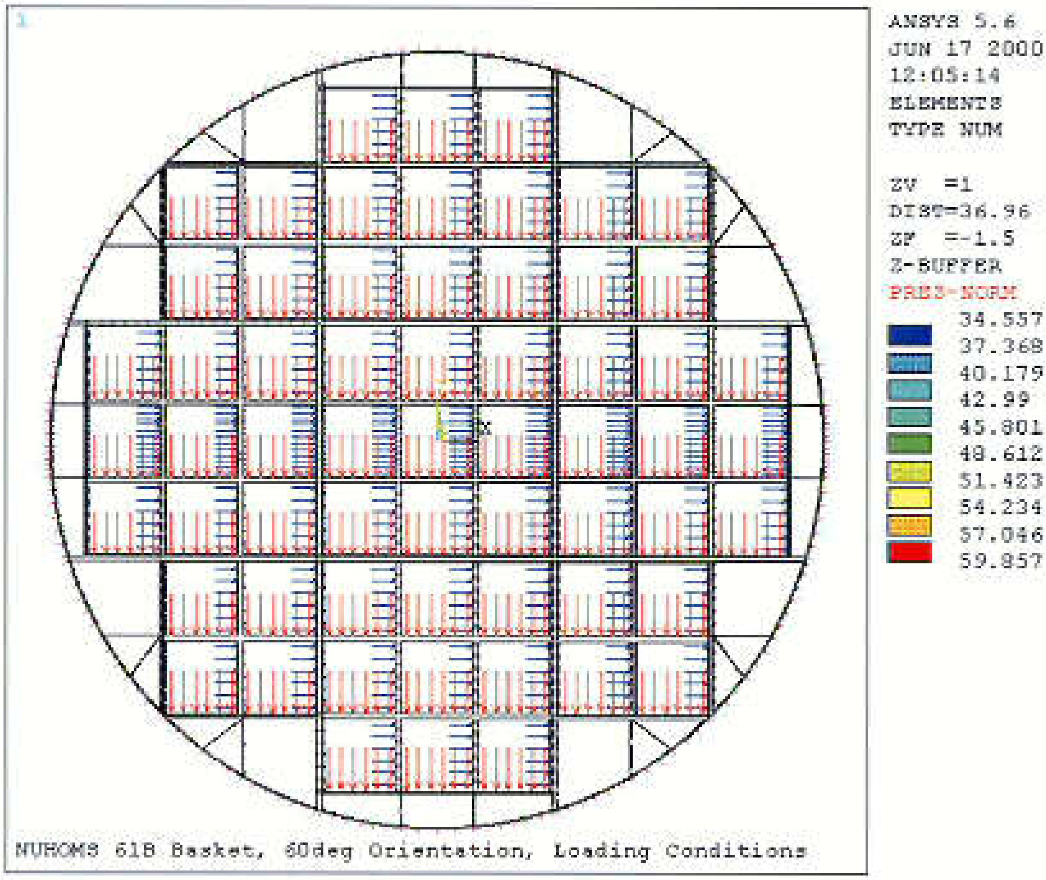


Figure K.3.7-4
60° Orientation Side Drop – Loading Conditions

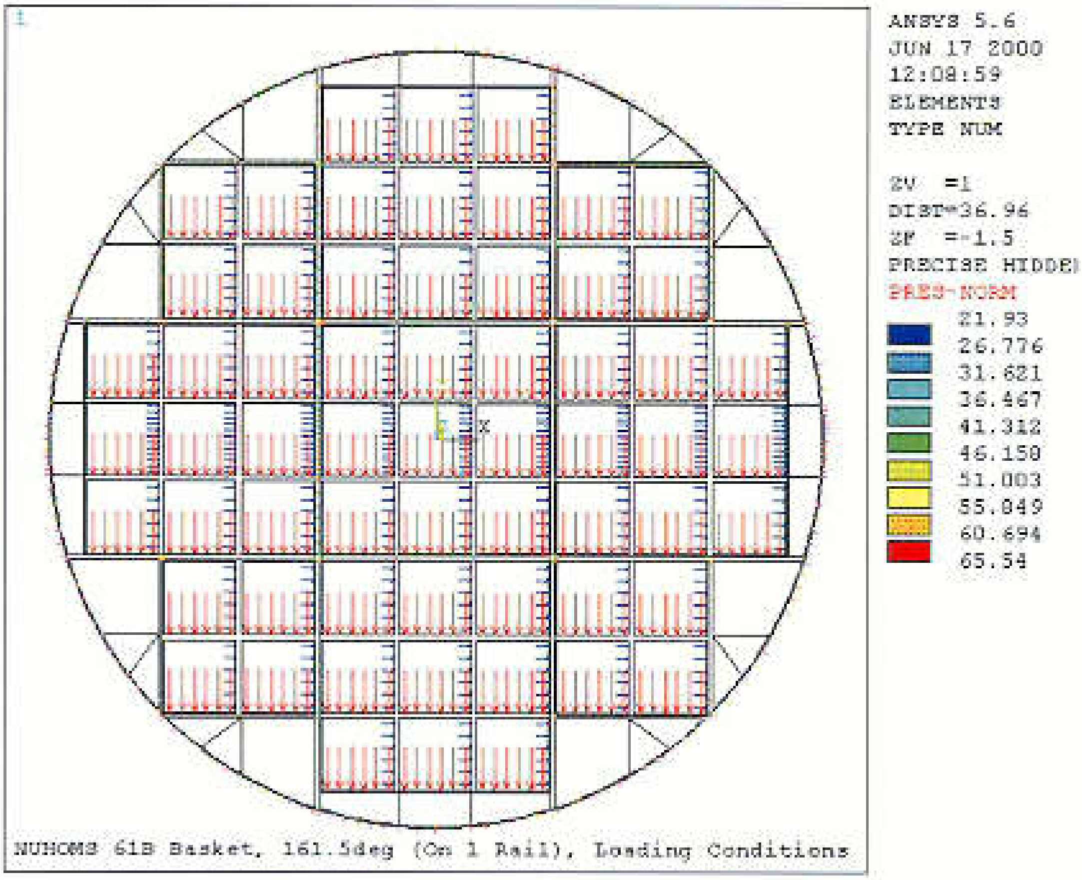


Figure K.3.7-5
161.5° Orientation Side Drop – Loading Conditions

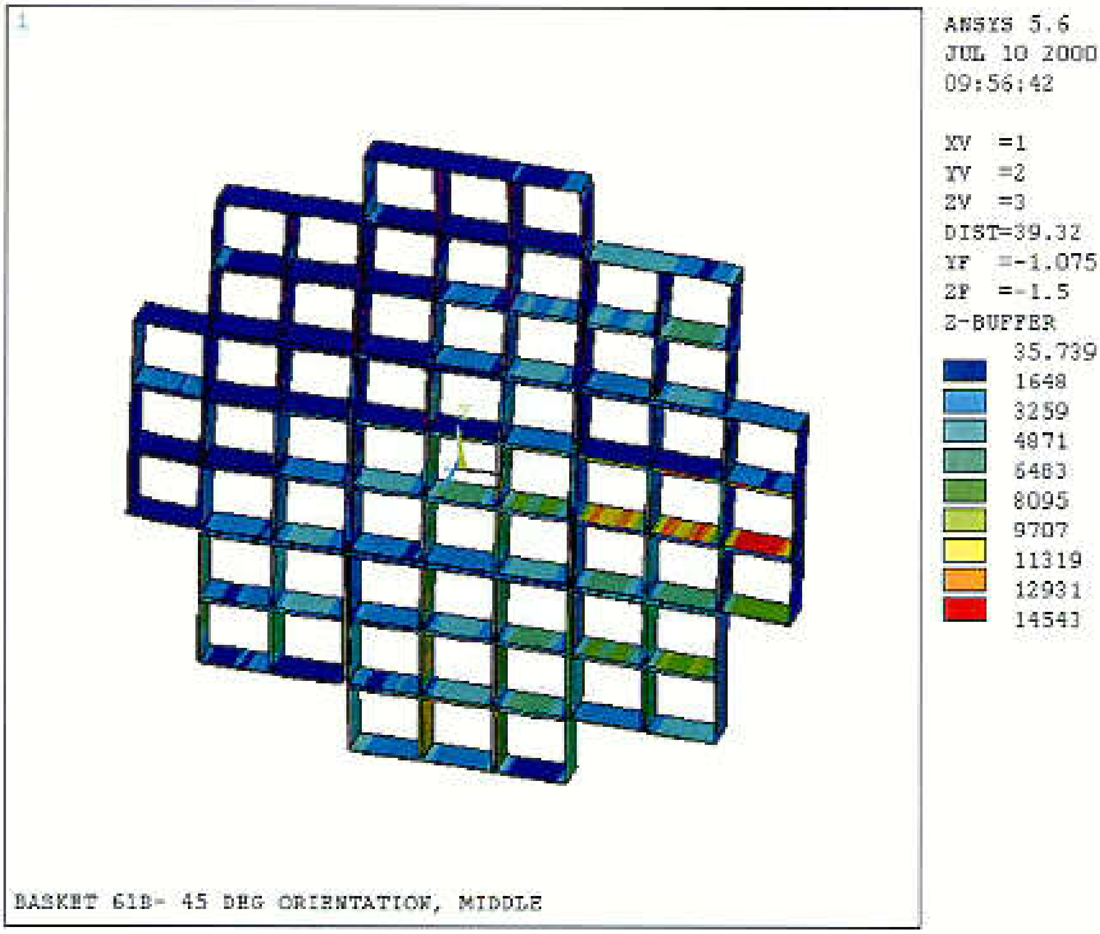


Figure K.3.7-6
45° Orientation Side Drop – Basket, P_m (75.5g)

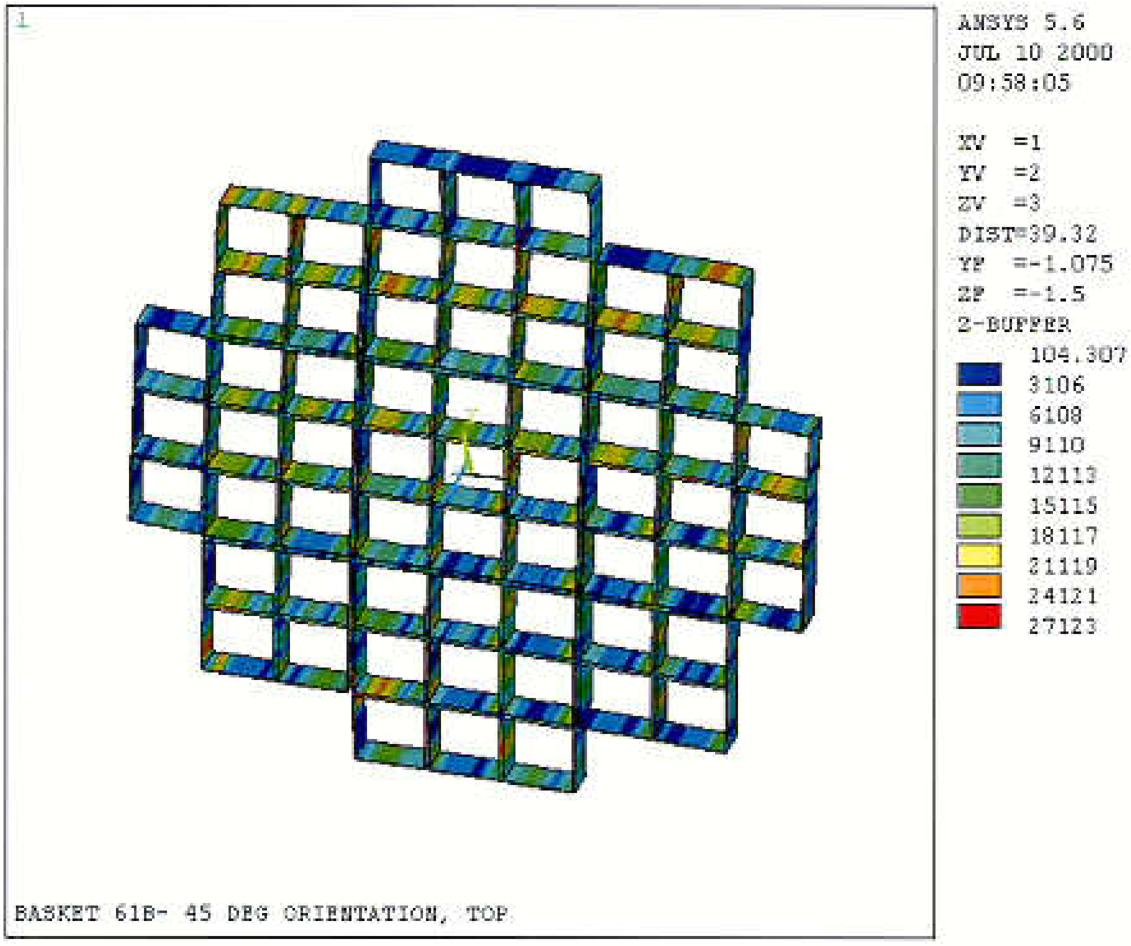


Figure K.3.7-7
45° Orientation Side Drop – Basket, $P_m + P_b$ (75.5g)

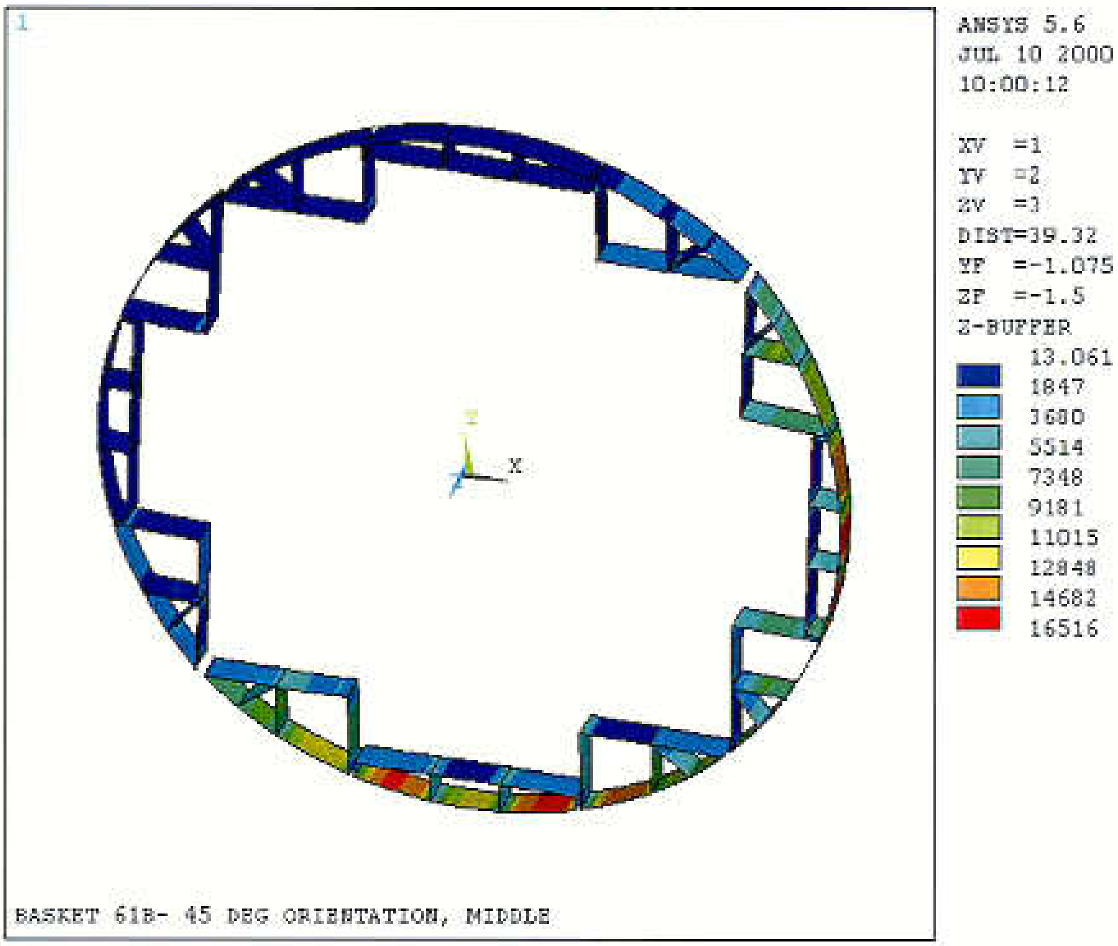


Figure K.3.7-8
45° Orientation Side Drop – Rails, P_m (75.5g)

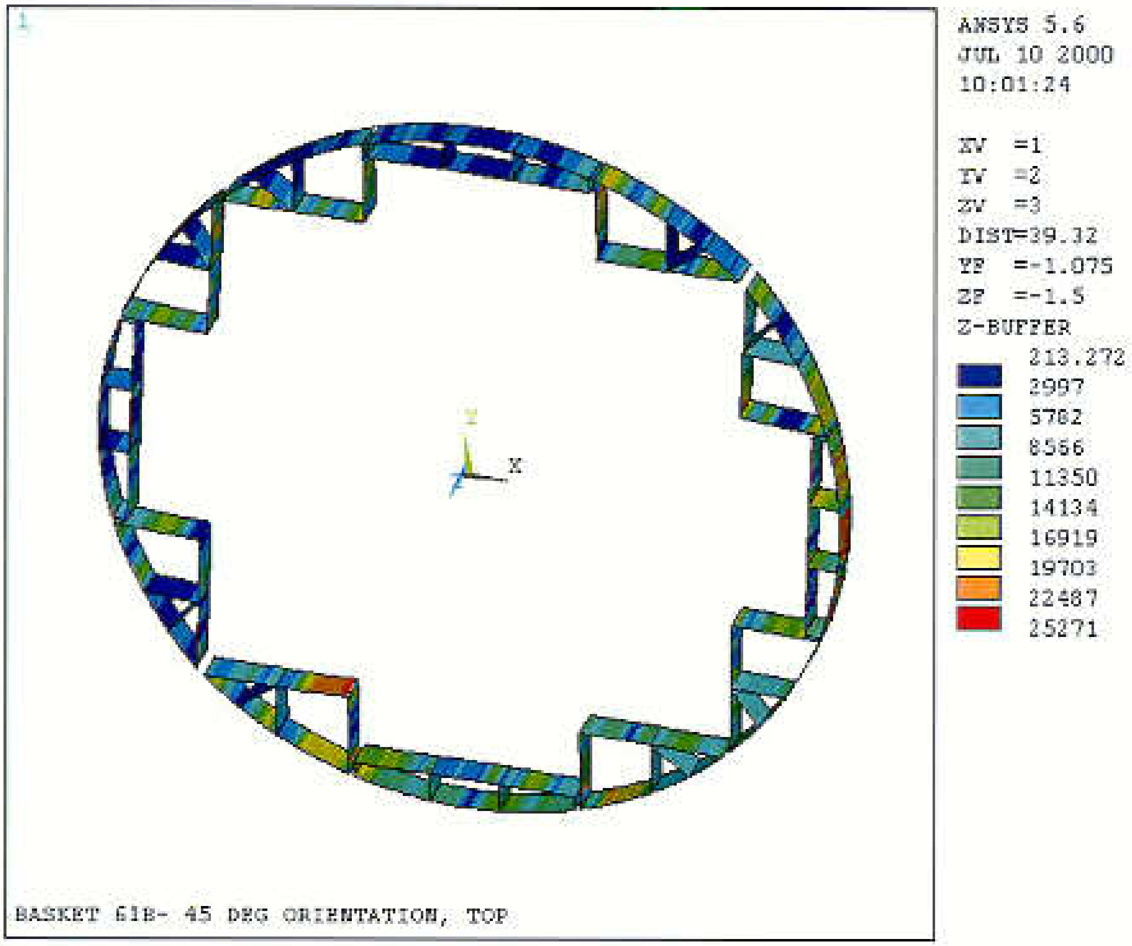


Figure K.3.7-9
45° Orientation Side Drop – Rails, $P_m + P_b$ (75.5g)

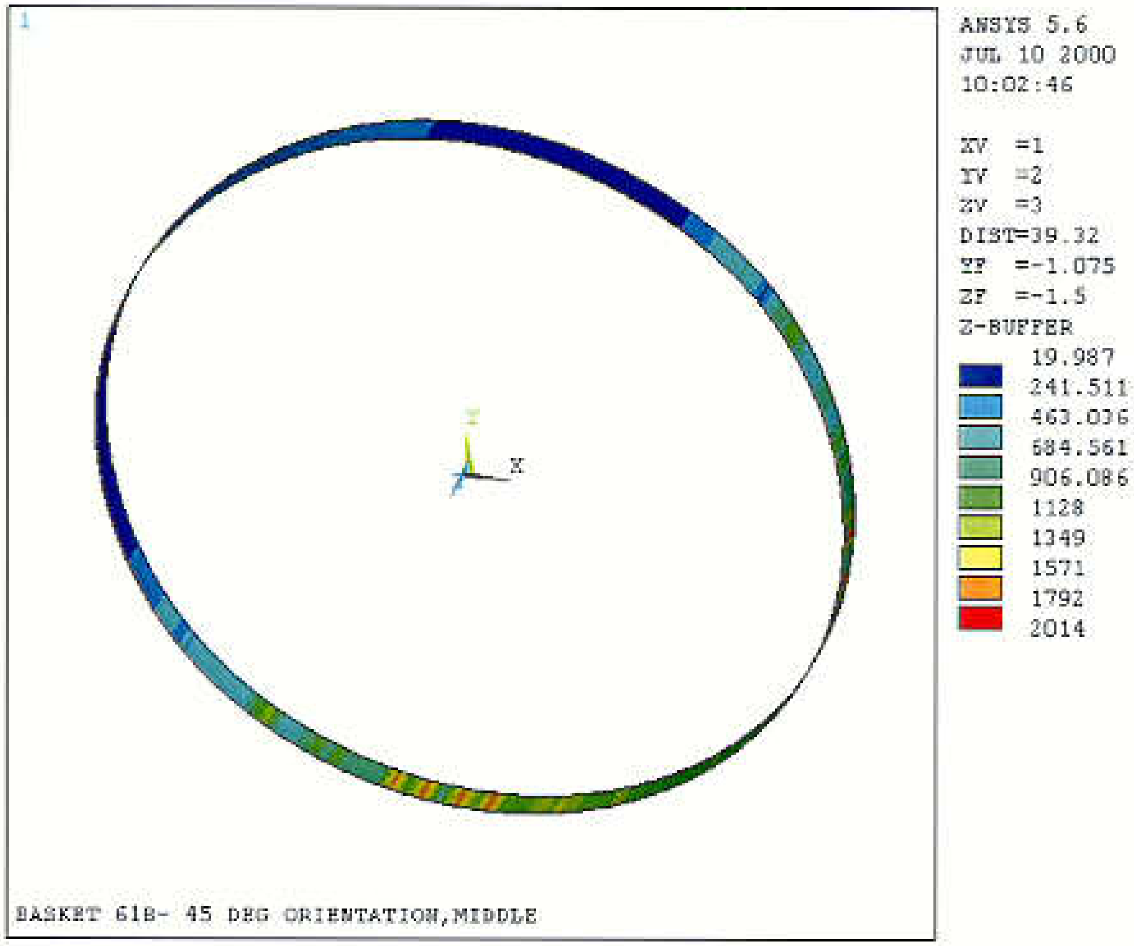


Figure K.3.7-10
45° Orientation Side Drop – Canister, P_m (75.5g)

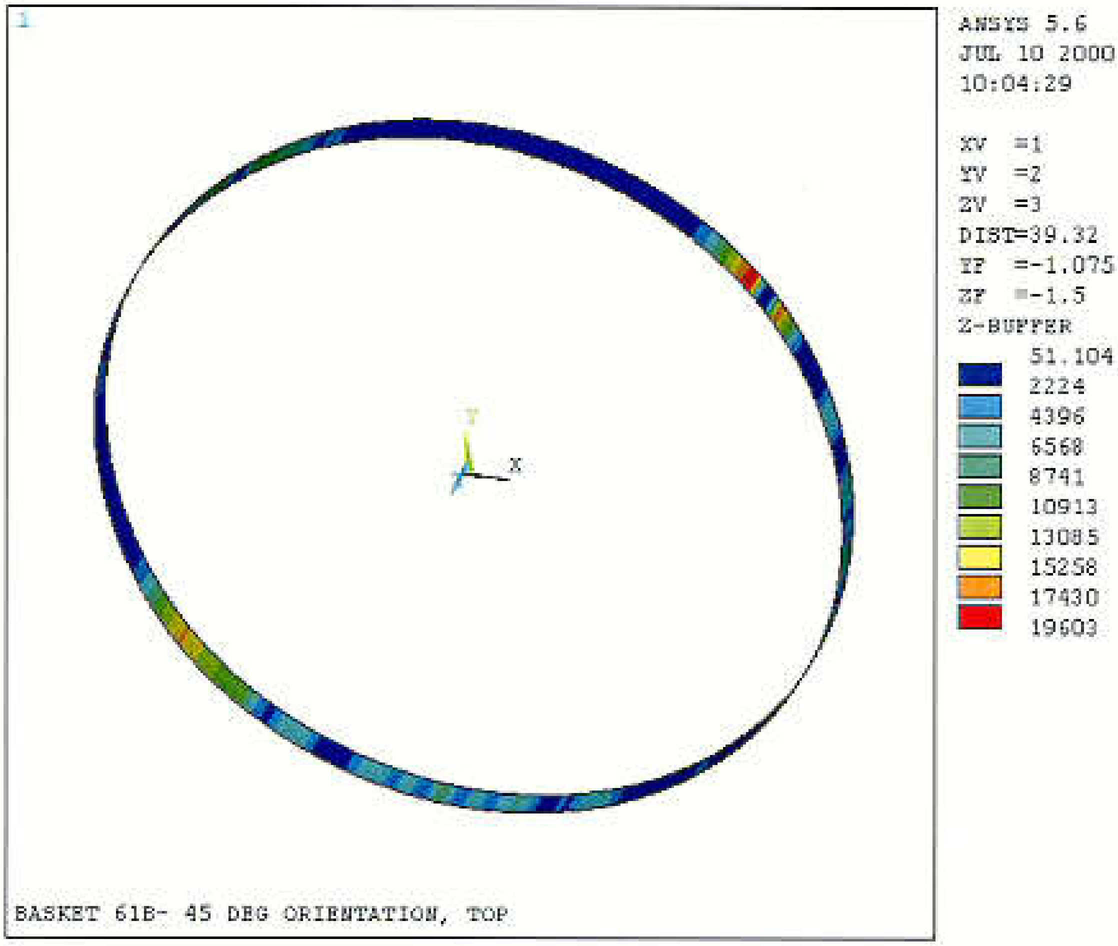


Figure K.3.7-11
45° Orientation Side Drop – Canister, $P_m + P_b$ (75.5g)

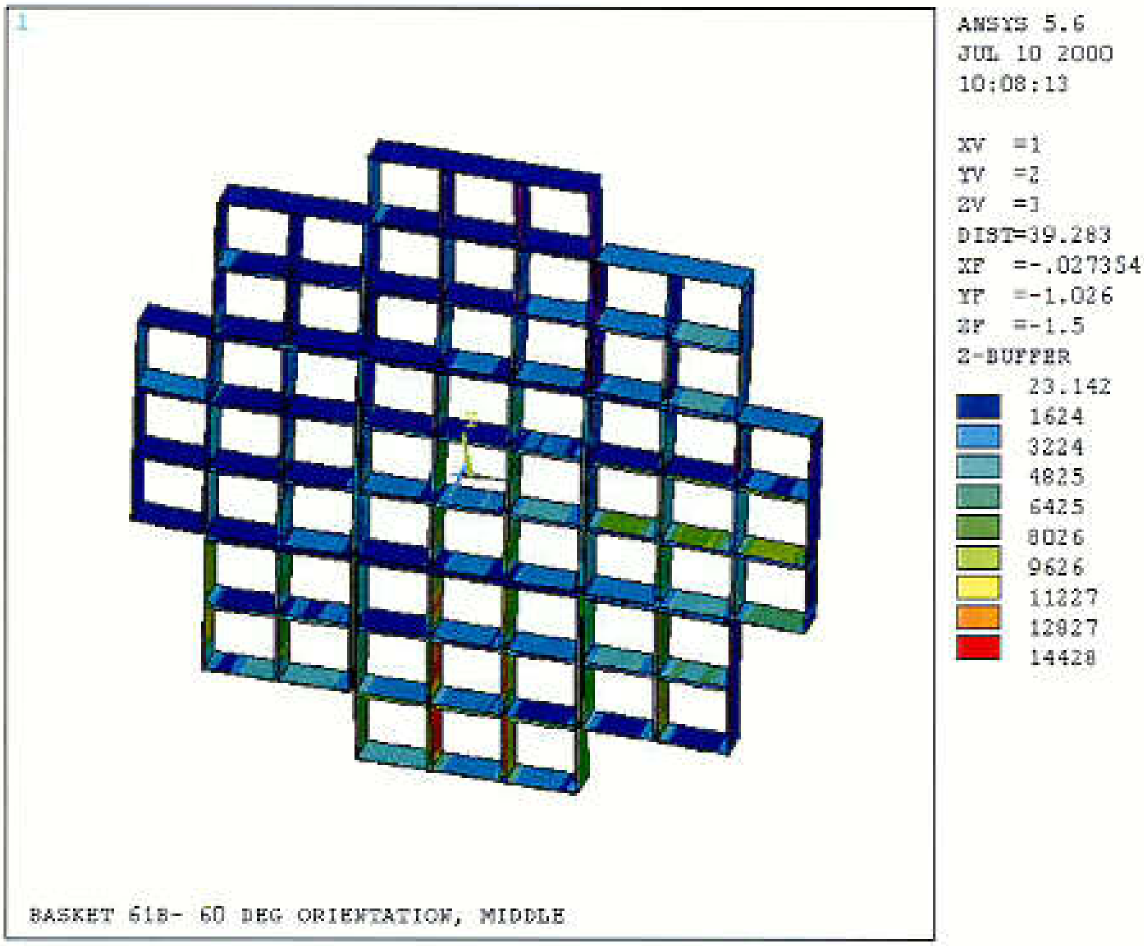


Figure K.3.7-12
60° Orientation Side Drop – Basket, P_m (75.5g)

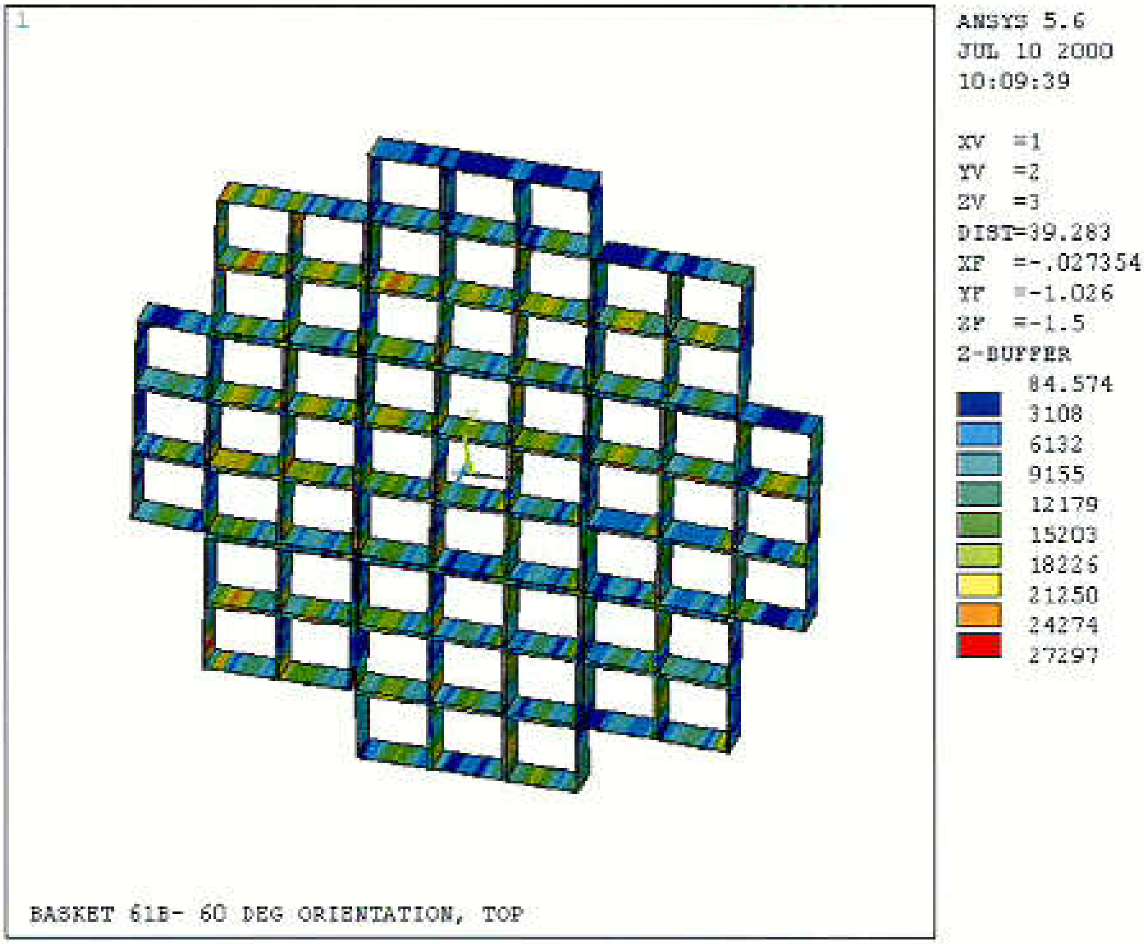


Figure K.3.7-13
60° Orientation Side Drop – Basket, $P_m + P_b$ (75.5g)

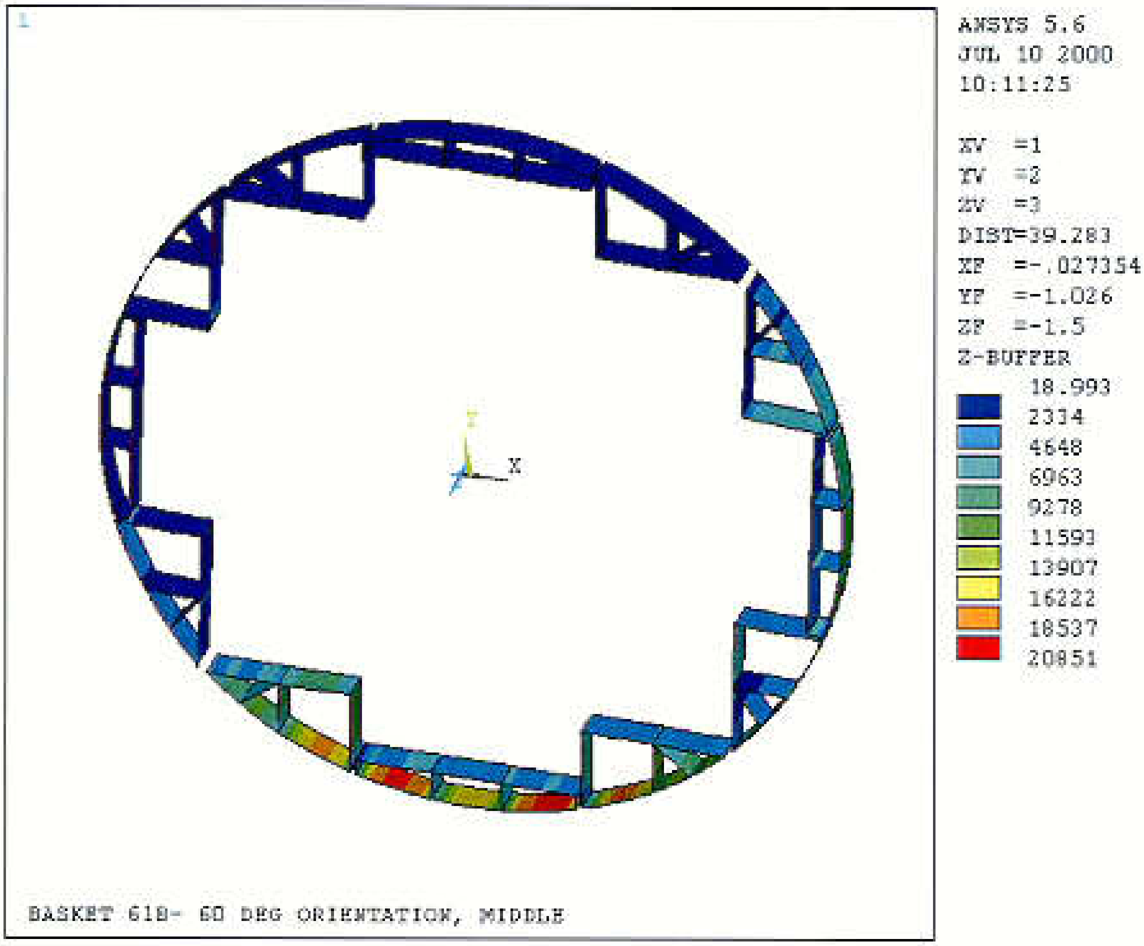


Figure K.3.7-14
60° Orientation Side Drop – Rails, P_m (75.5g)

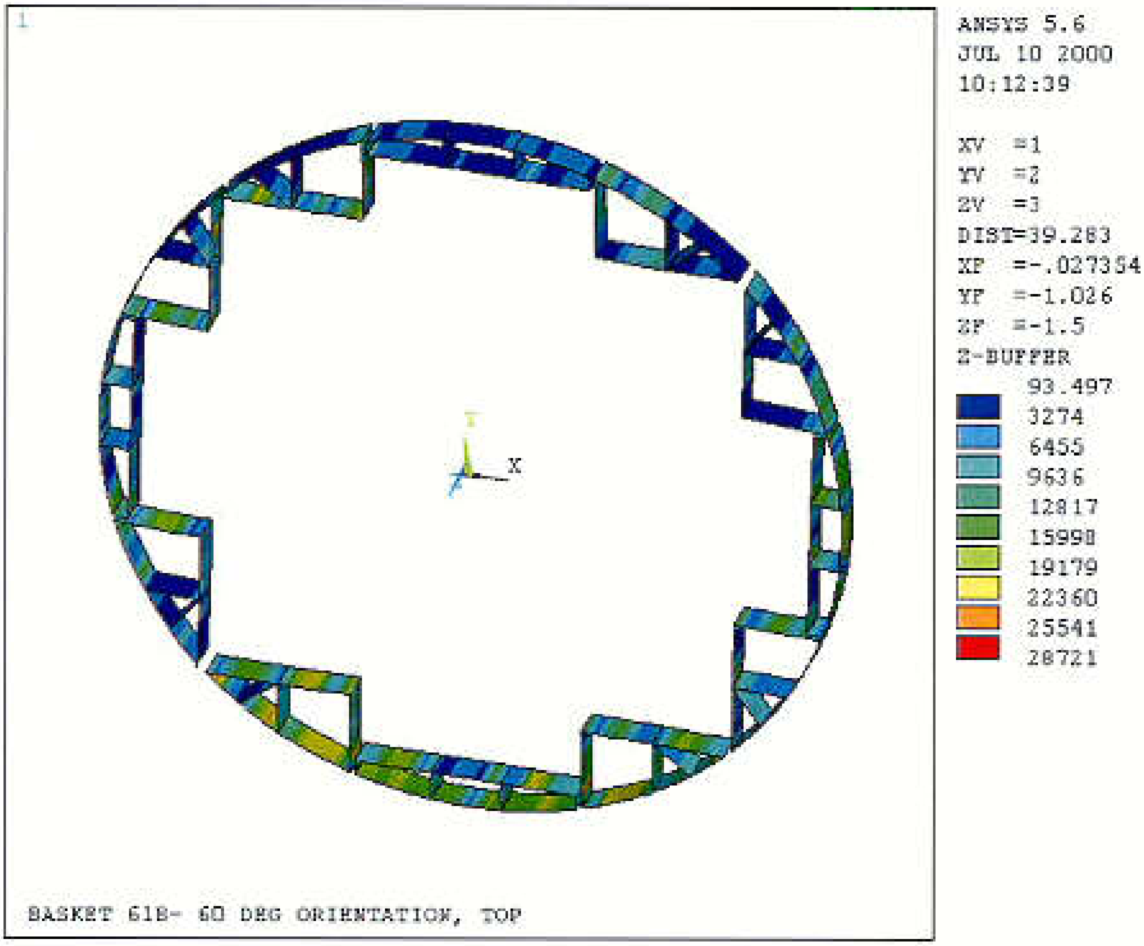


Figure K.3.7-15
60° Orientation Side Drop – Rails, $P_m + P_b$ (75.5g)

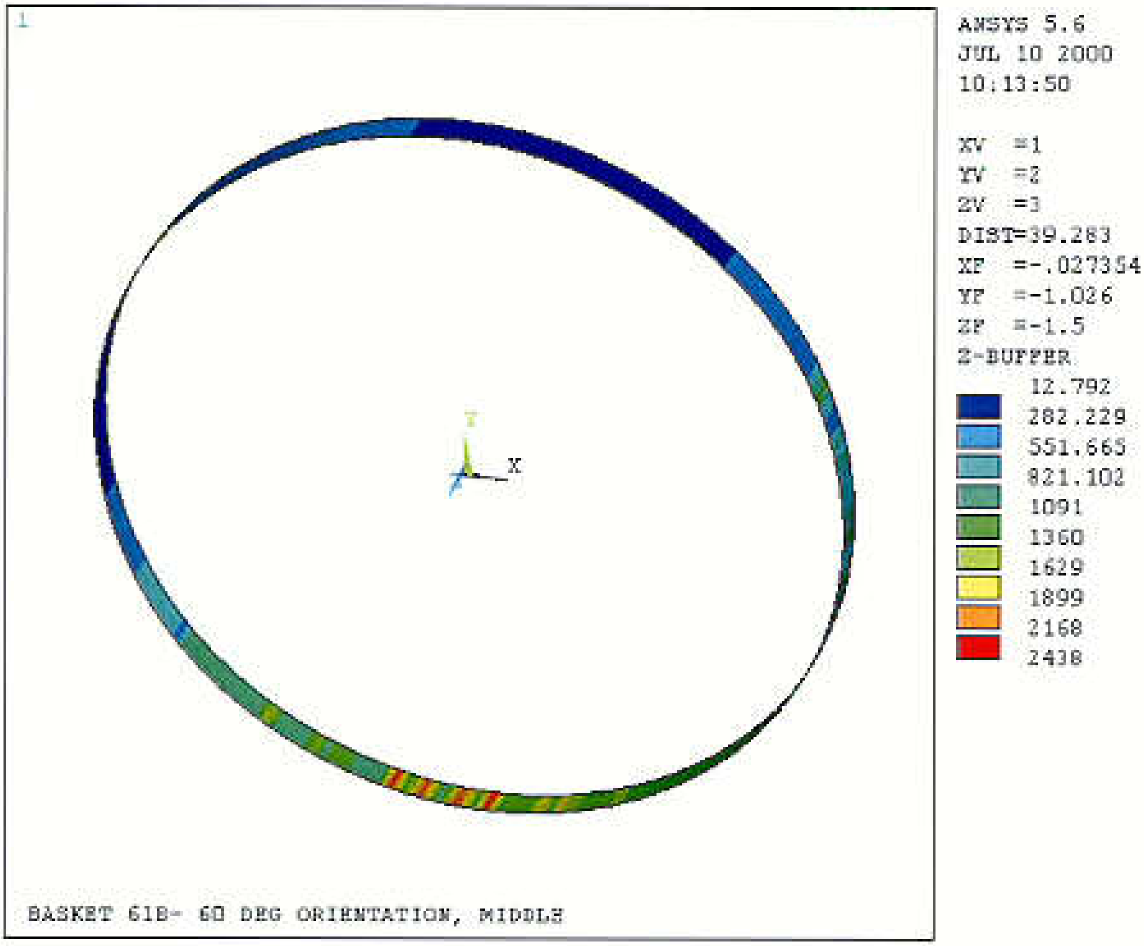


Figure K.3.7-16
60° Orientation Side Drop – Canister, P_m (75.5g)

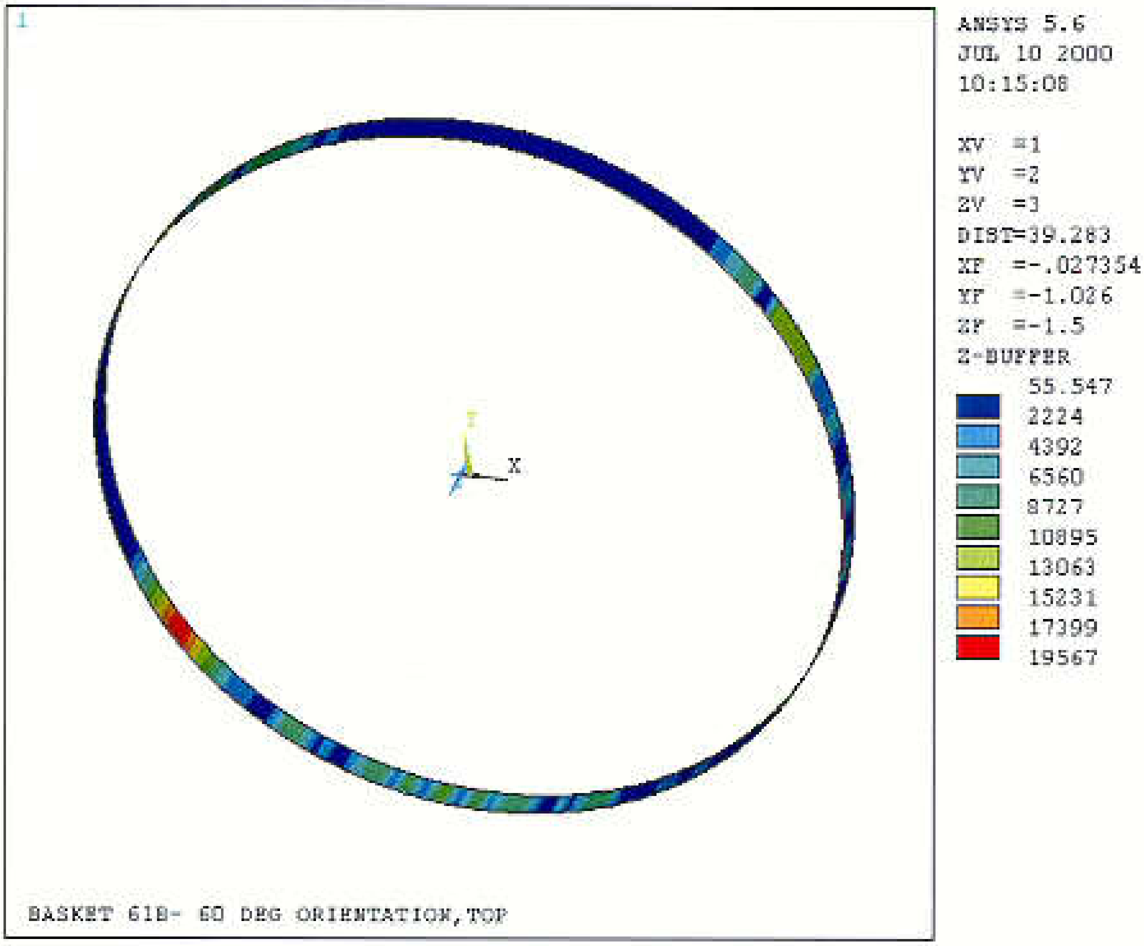


Figure K.3.7-17
60° Orientation Side Drop – Canister, $P_m + P_b$ (75.5g)

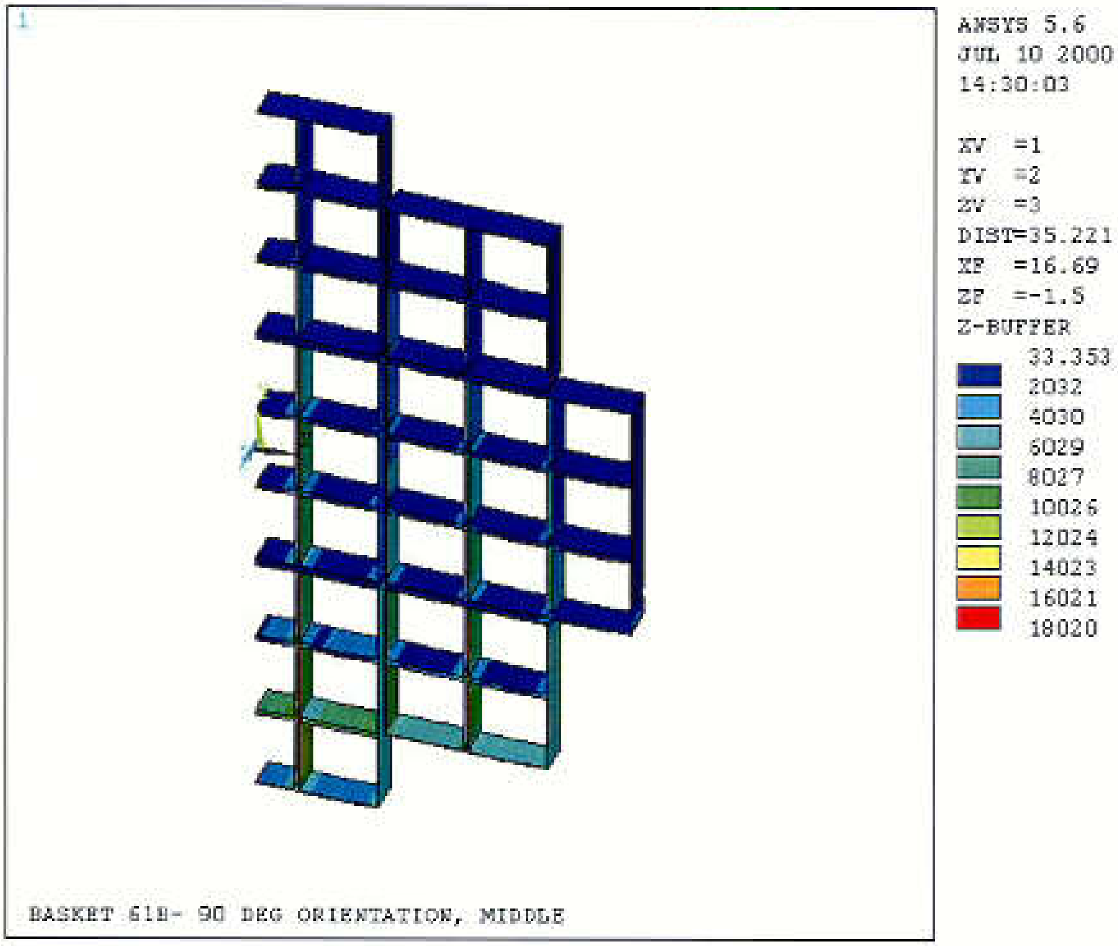


Figure K.3.7-18
90° Orientation Side Drop – Basket, P_m (75.5g)

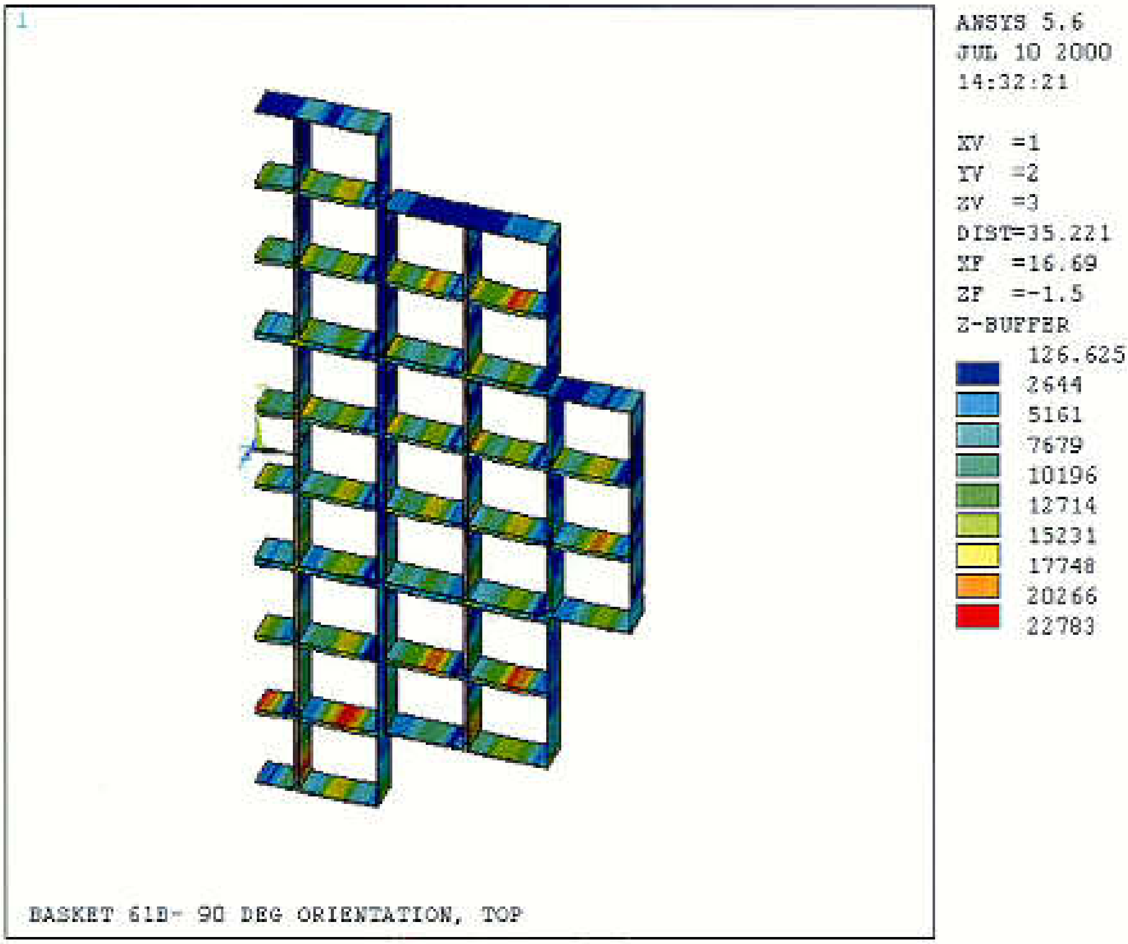


Figure K.3.7-19
90° Orientation Side Drop – Basket, $P_m + P_b$ (75.5g)

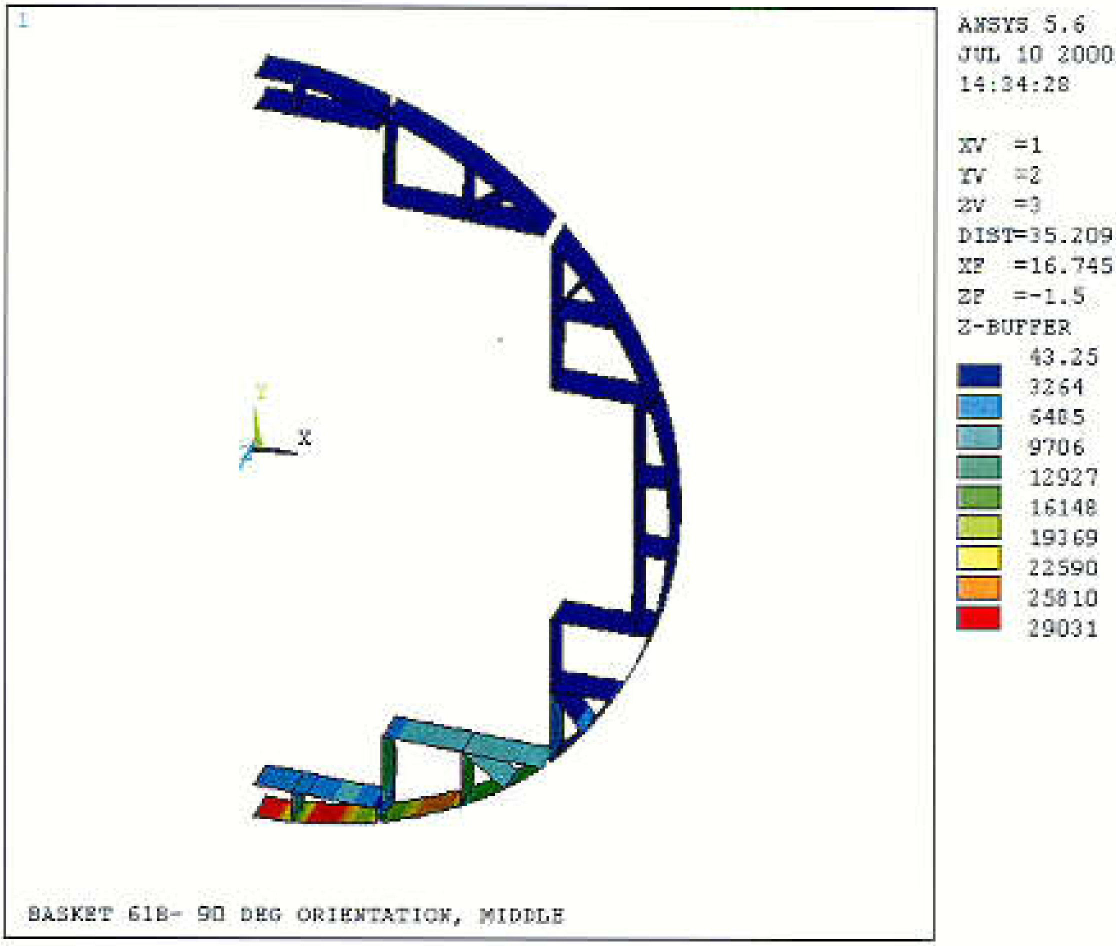


Figure K.3.7-20
90° Orientation Side Drop – Rails, P_m (75.5g)

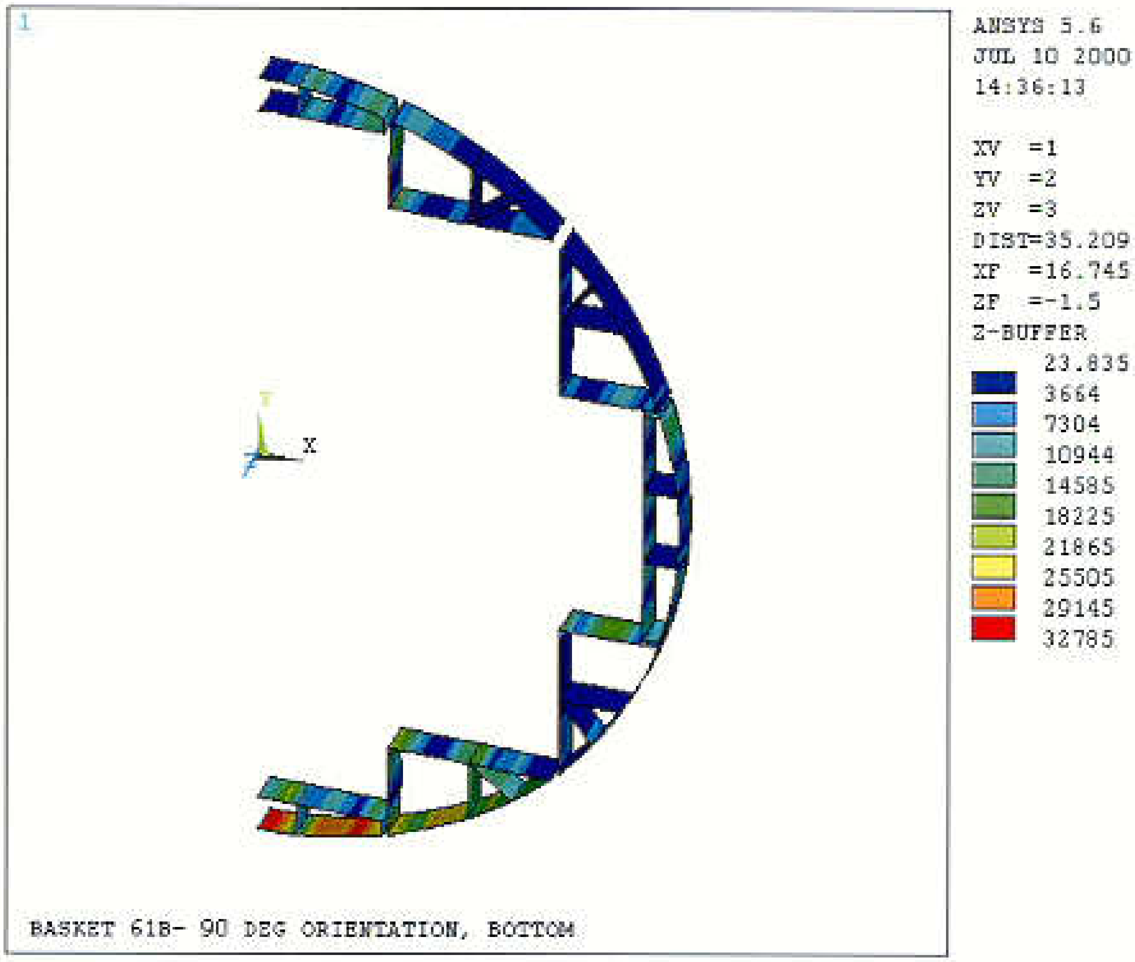


Figure K.3.7-21
90° Orientation Side Drop – Rails, $P_m + P_b$ (75.5g)

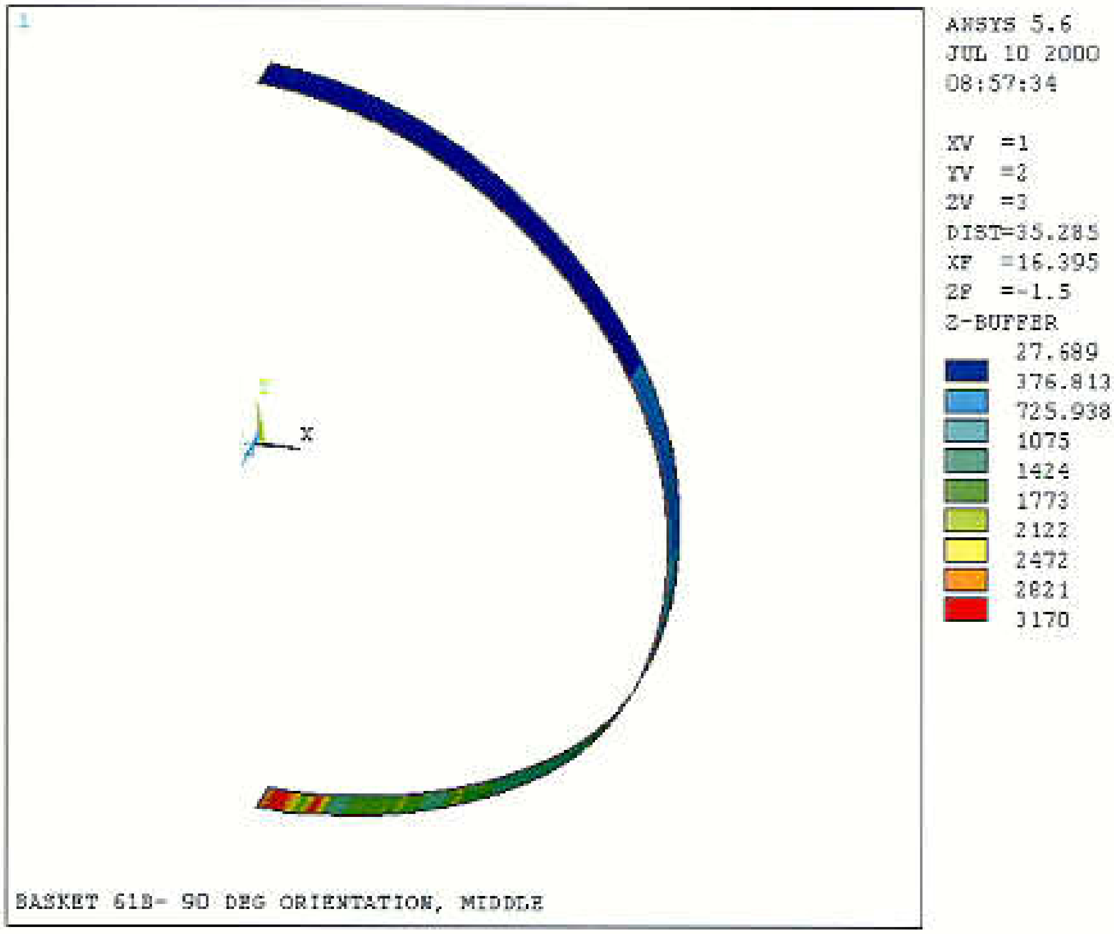


Figure K.3.7-22
90° Orientation Drop – Canister, P_m (75.5g)

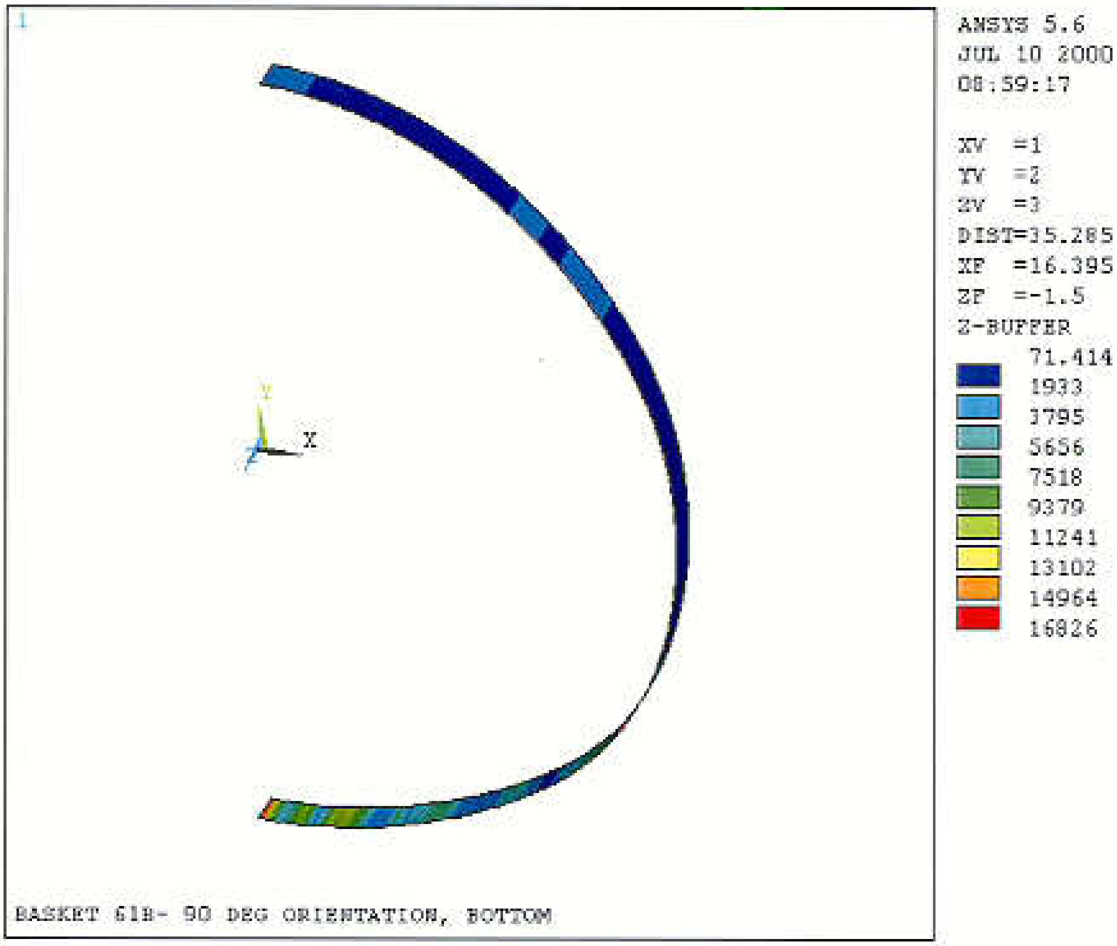


Figure K.3.7-23
90° Orientation Side Drop– Canister, $P_m + P_b$ (75.5g)

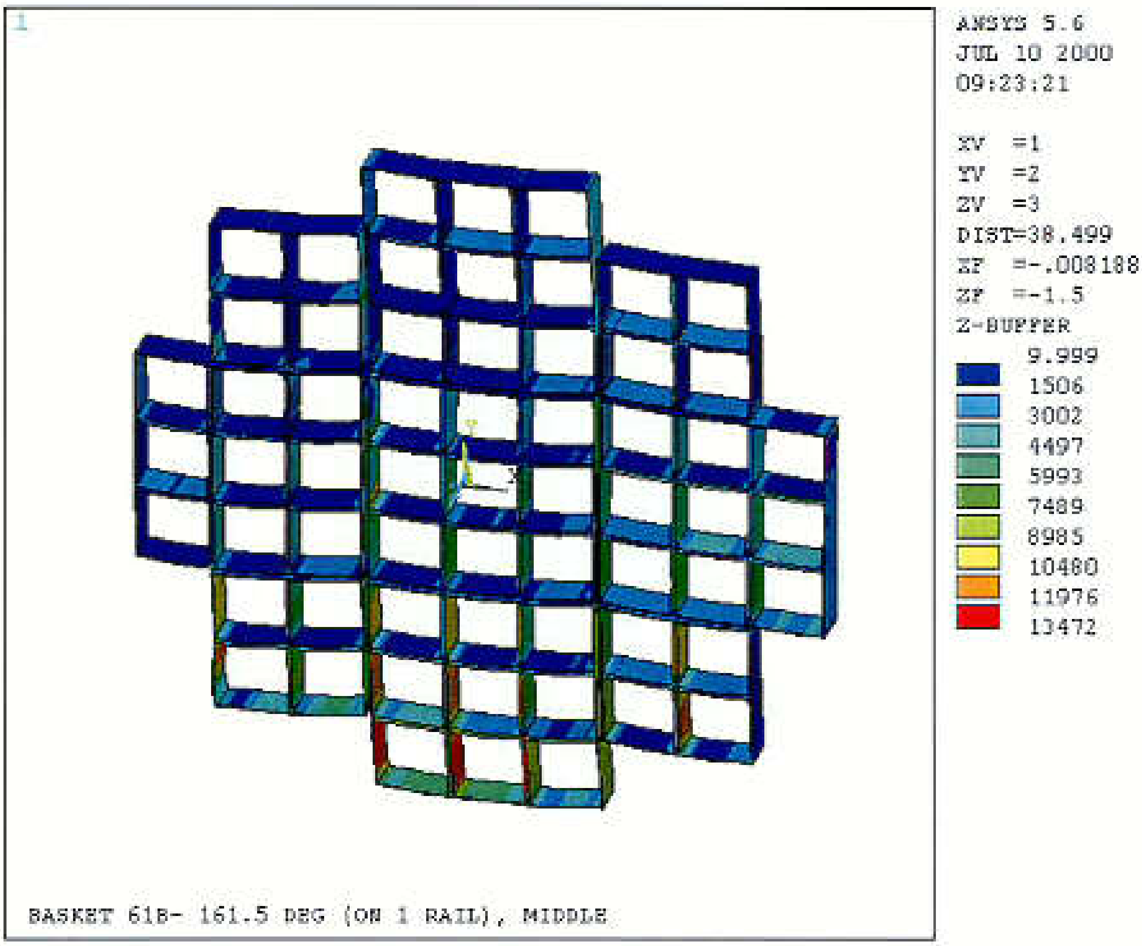


Figure K.3.7-24
161.5° Orientation Side Drop – Basket, P_m (75.5g)

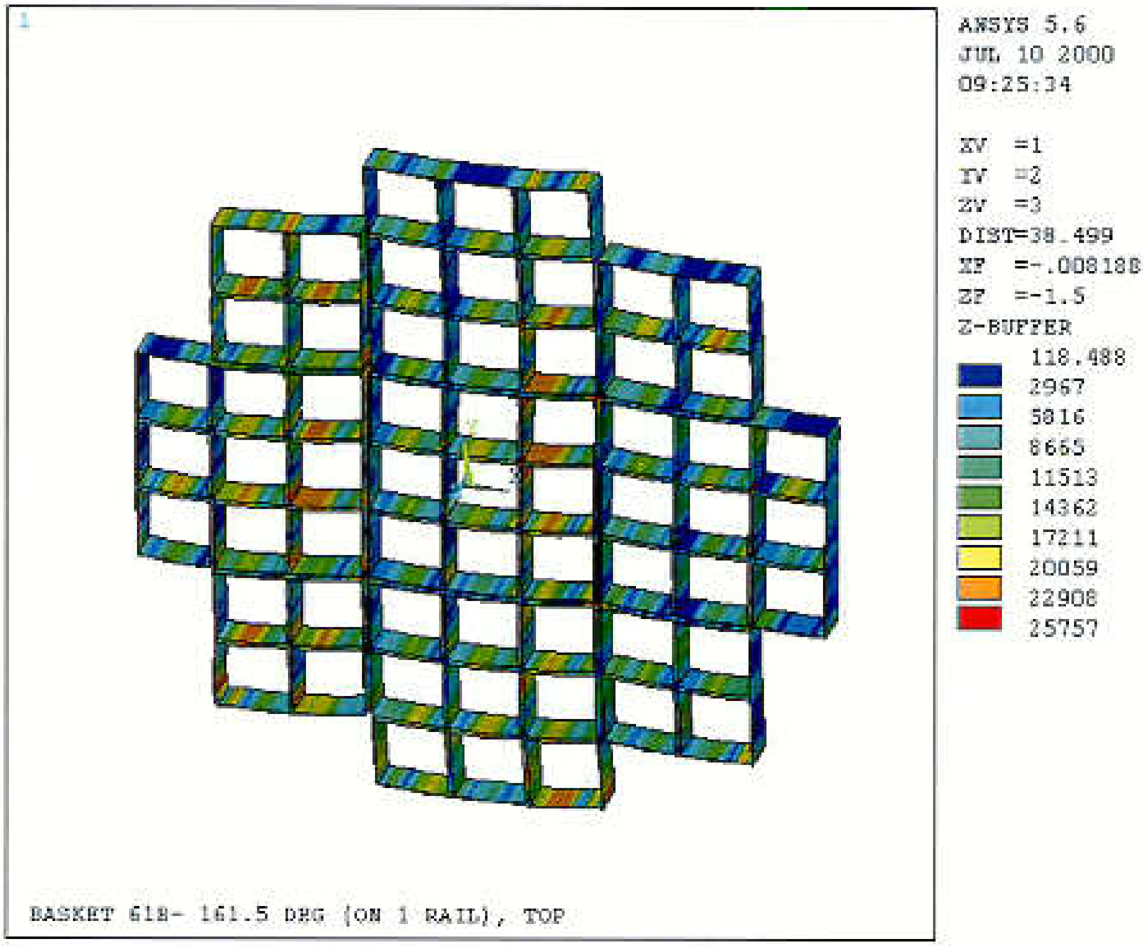


Figure K.3.7-25
161.5° Orientation Side Drop – Basket, $P_m + P_b$ (75.5g)

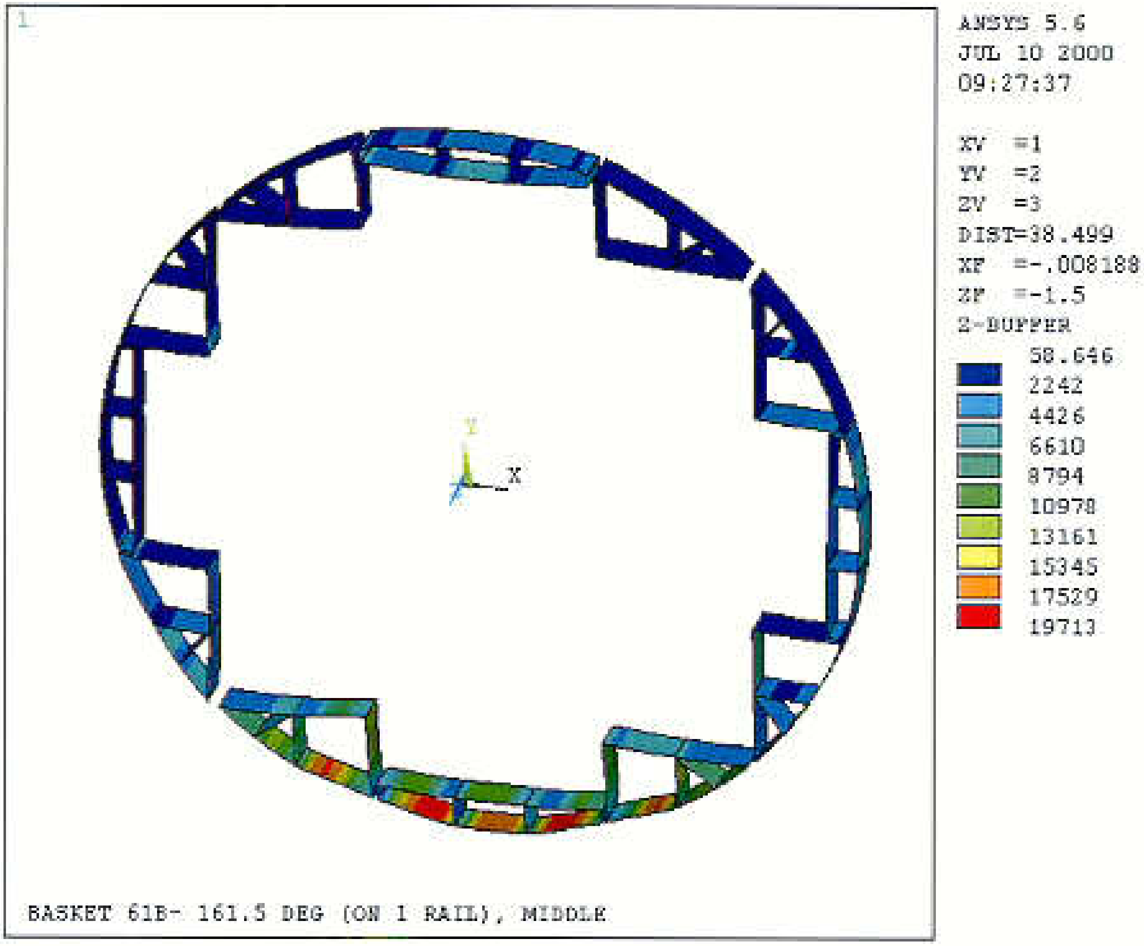


Figure K.3.7-26
161.5° Orientation Side Drop – Rails, P_m (75.5g)

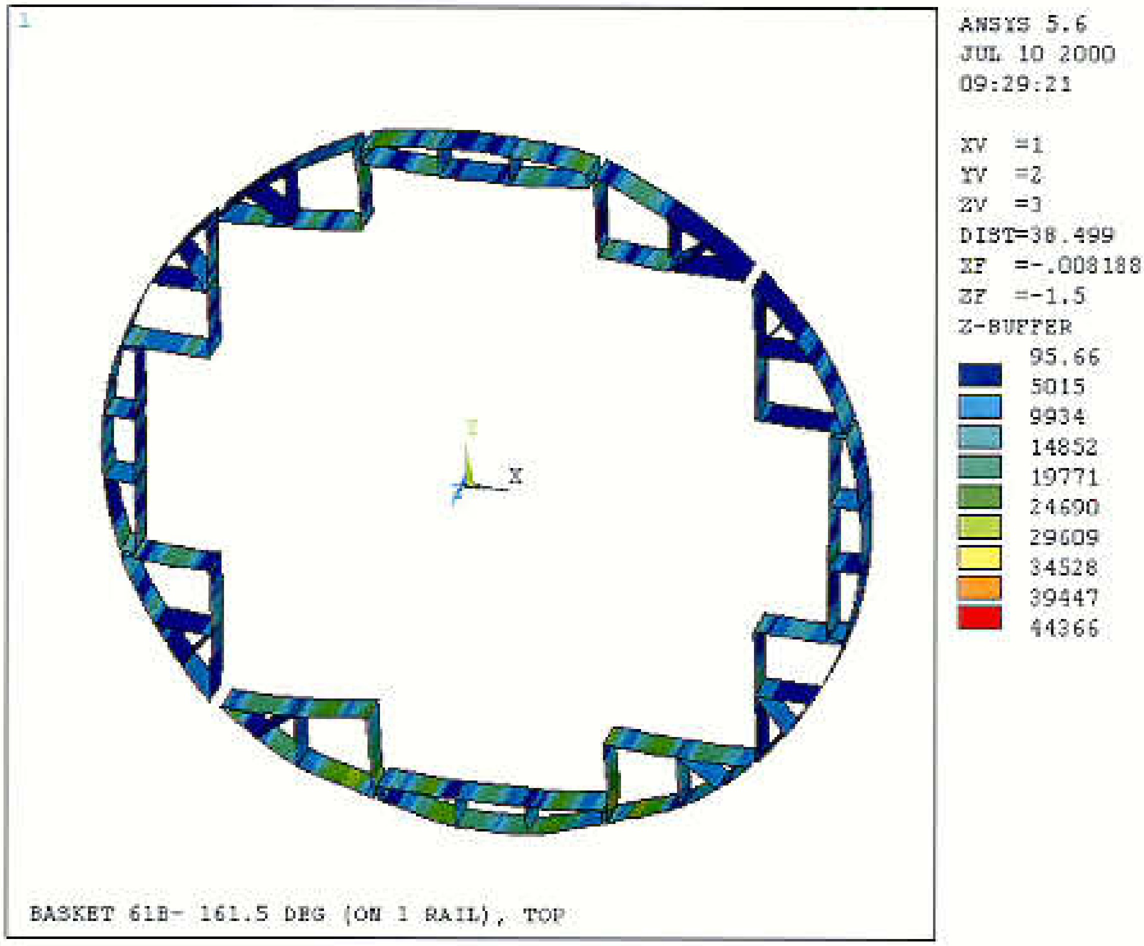


Figure K.3.7-27
161.5° Orientation Side Drop – Rails, $P_m + P_b$ (75.5g)

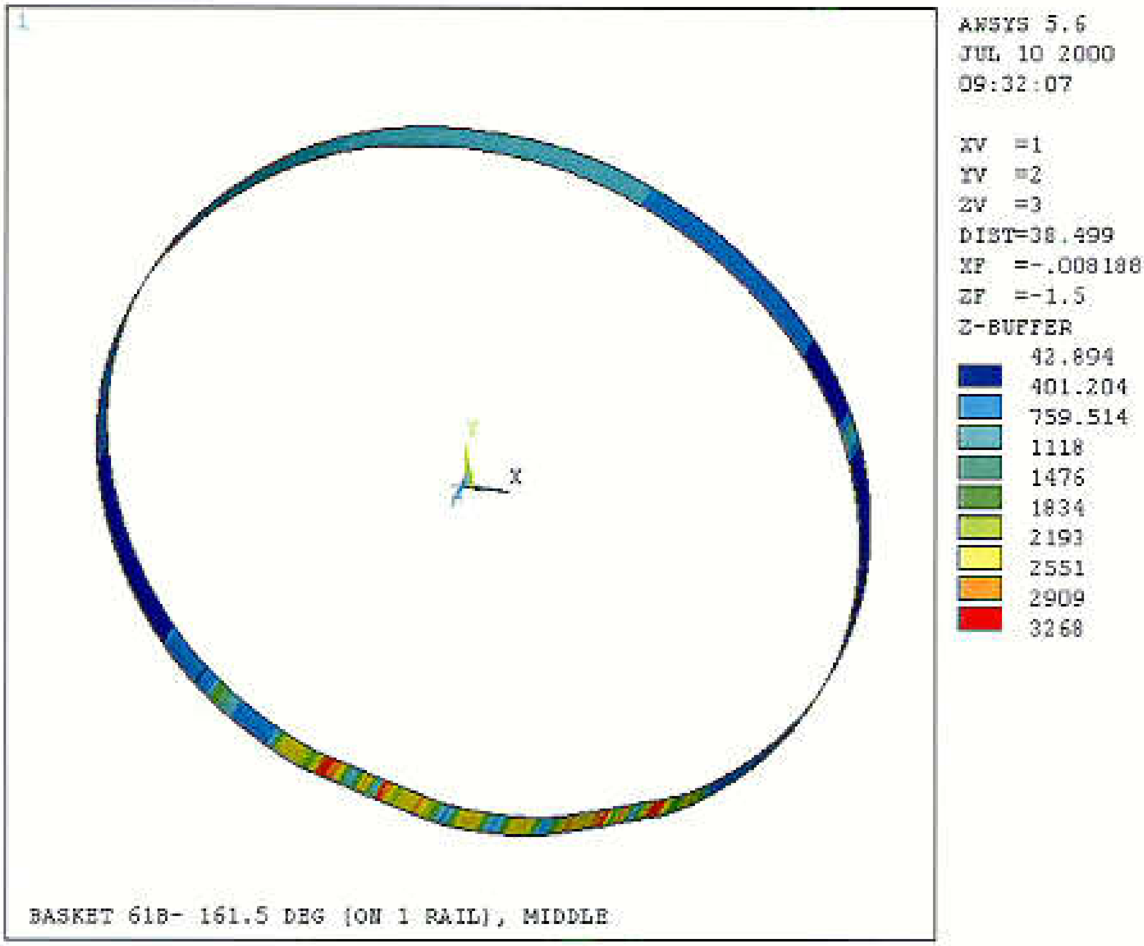


Figure K.3.7-28
161.5° Orientation Side Drop – Canister, P_m (75.5g)

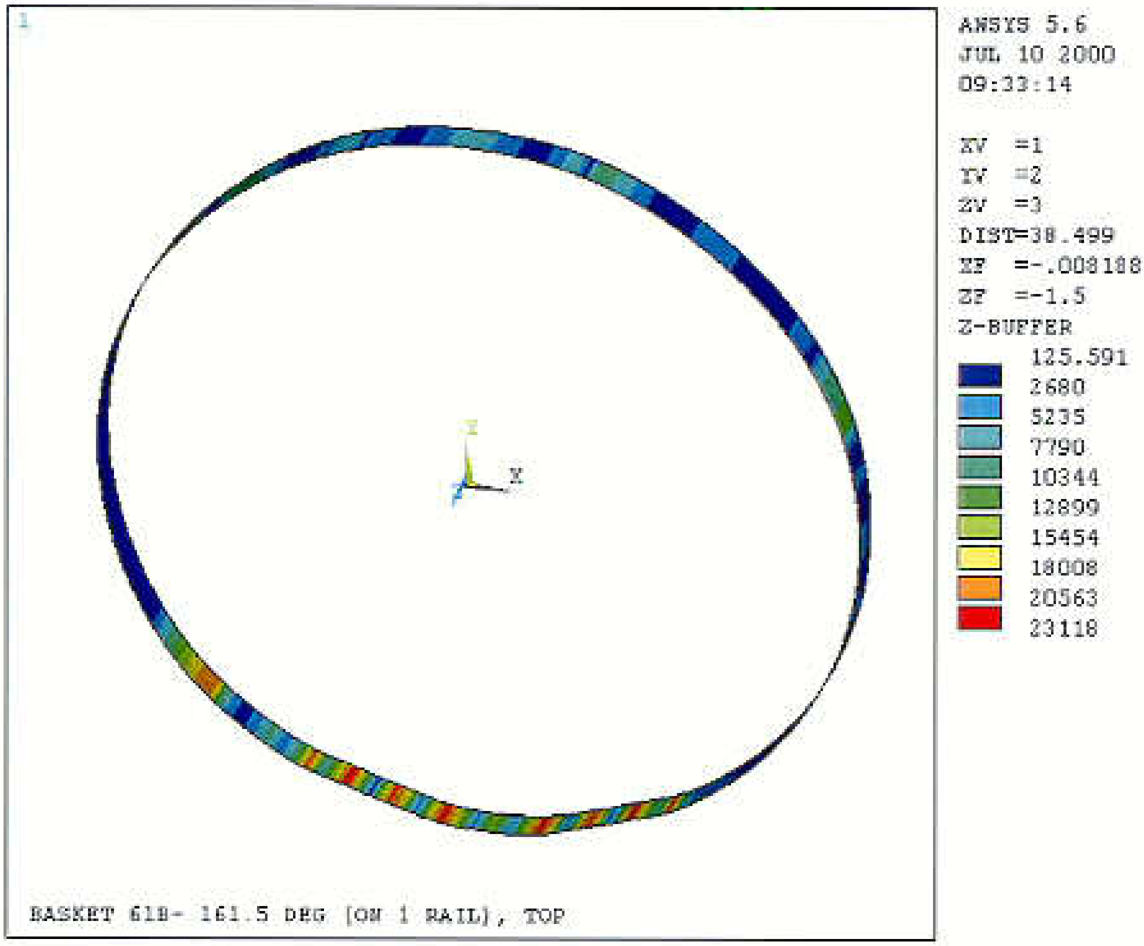


Figure K.3.7-29
161.5° Orientation Side Drop – Canister, $P_m + P_b$ (75.5g)

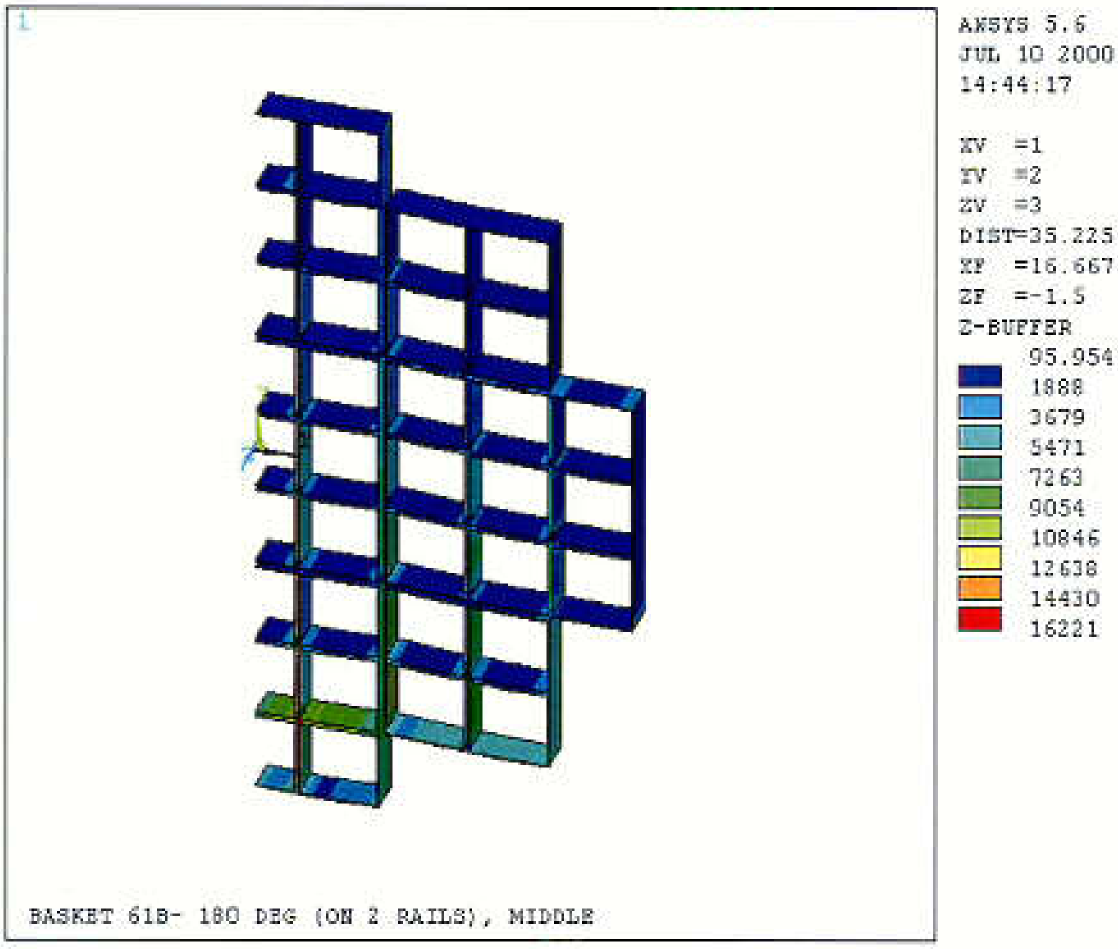


Figure K.3.7-30
180° Orientation Side Drop – Basket, P_m (75.5g)

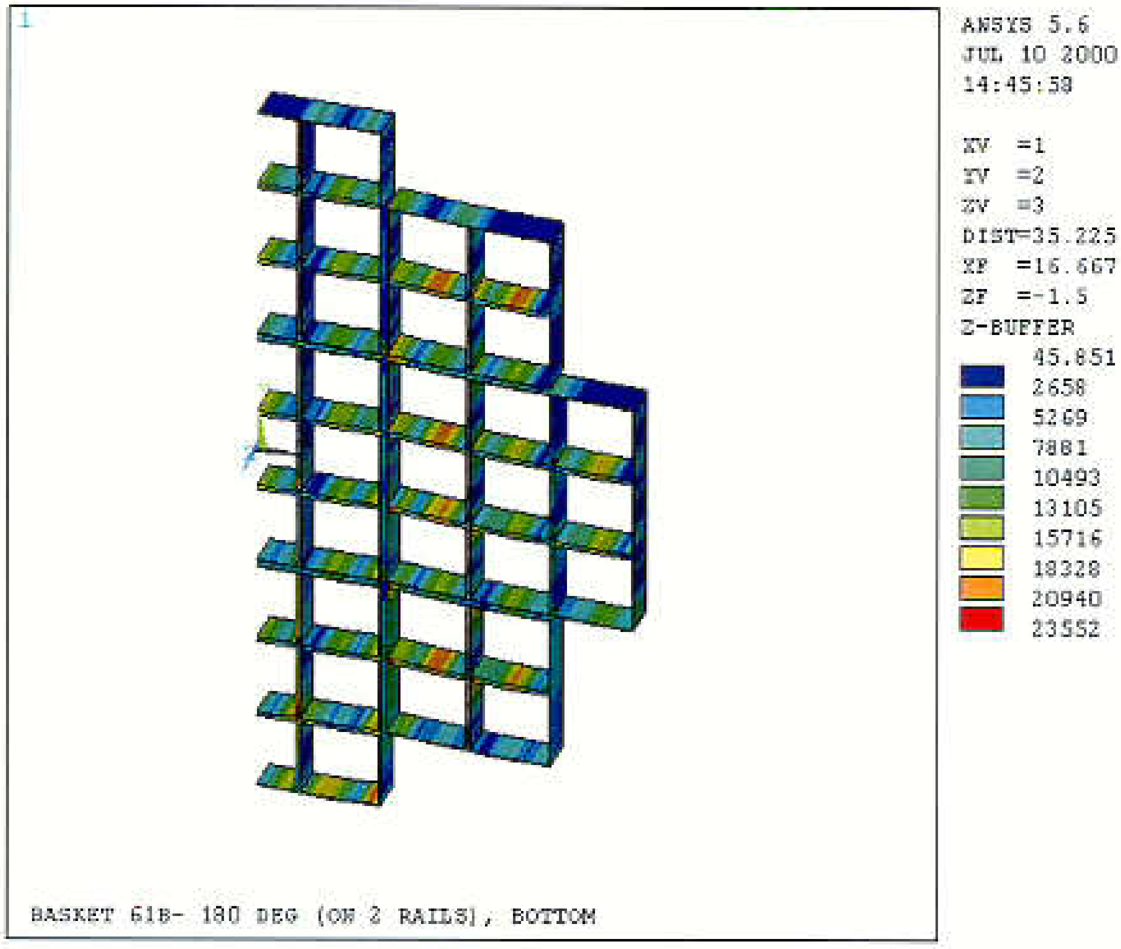


Figure K.3.7-31
180° Orientation Side Drop – Basket, $P_m + P_b$ (75.5g)

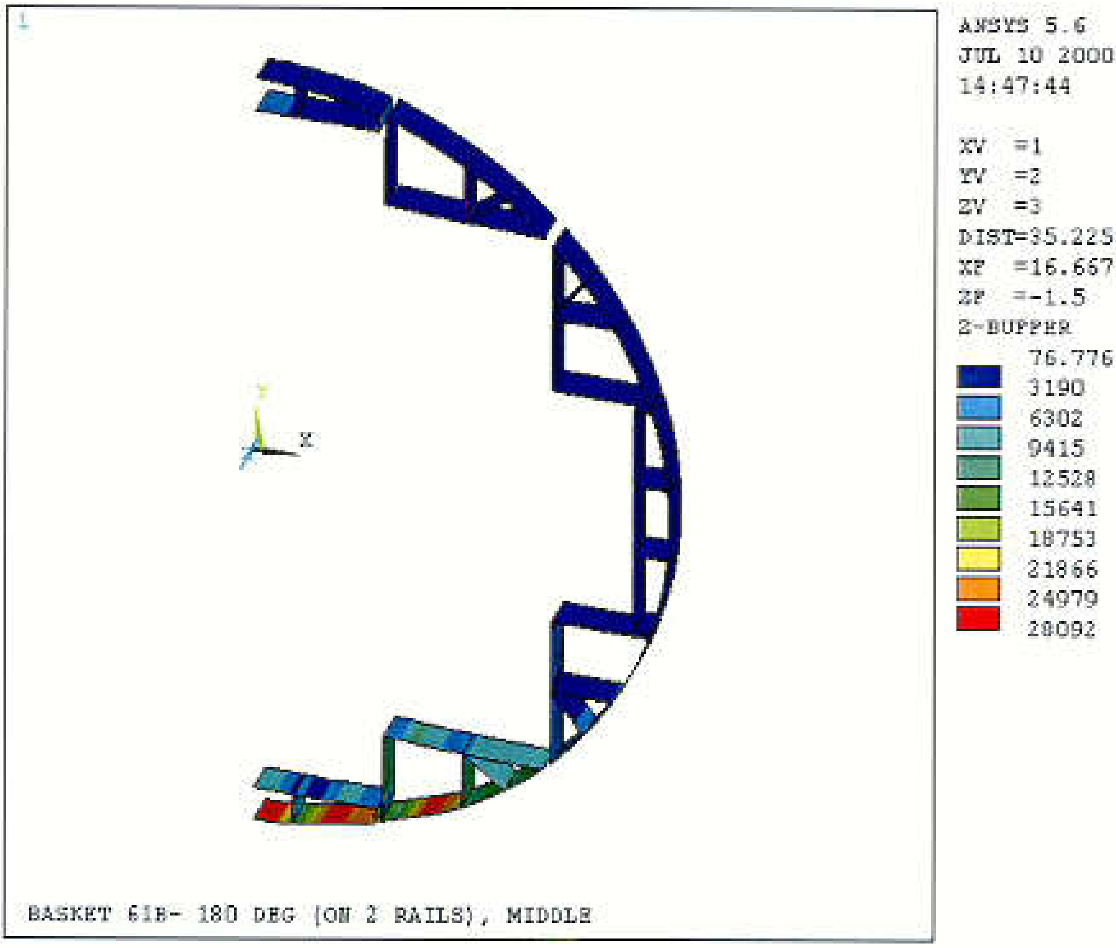


Figure K.3.7-32
180° Orientation Side Drop – Rails, P_m (75.5g)

Figure K.3.7-33
180° Orientation Side Drop – Rails, $P_m + P_b$ (75.5g)

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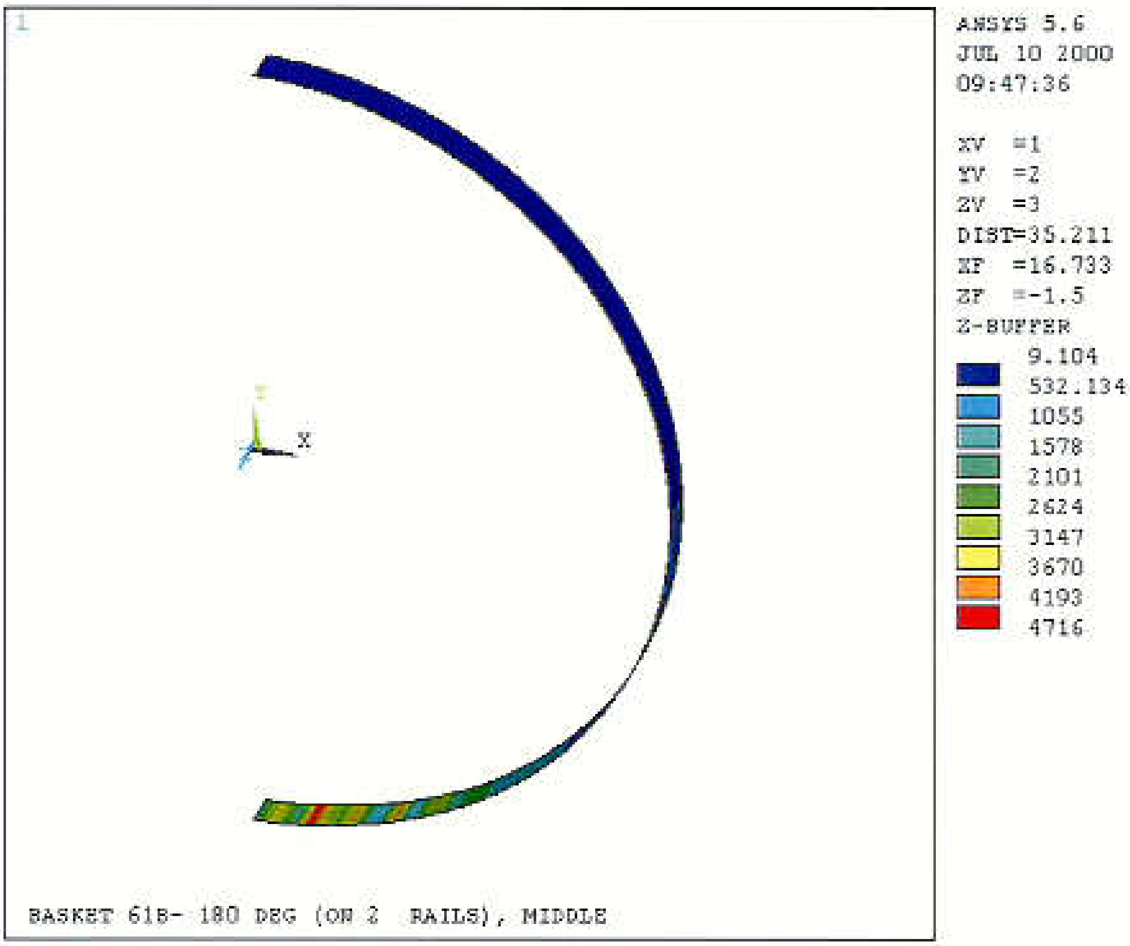

Figure K.3.7-34
180° Orientation side Drop – Canister, P_m (75.5g)

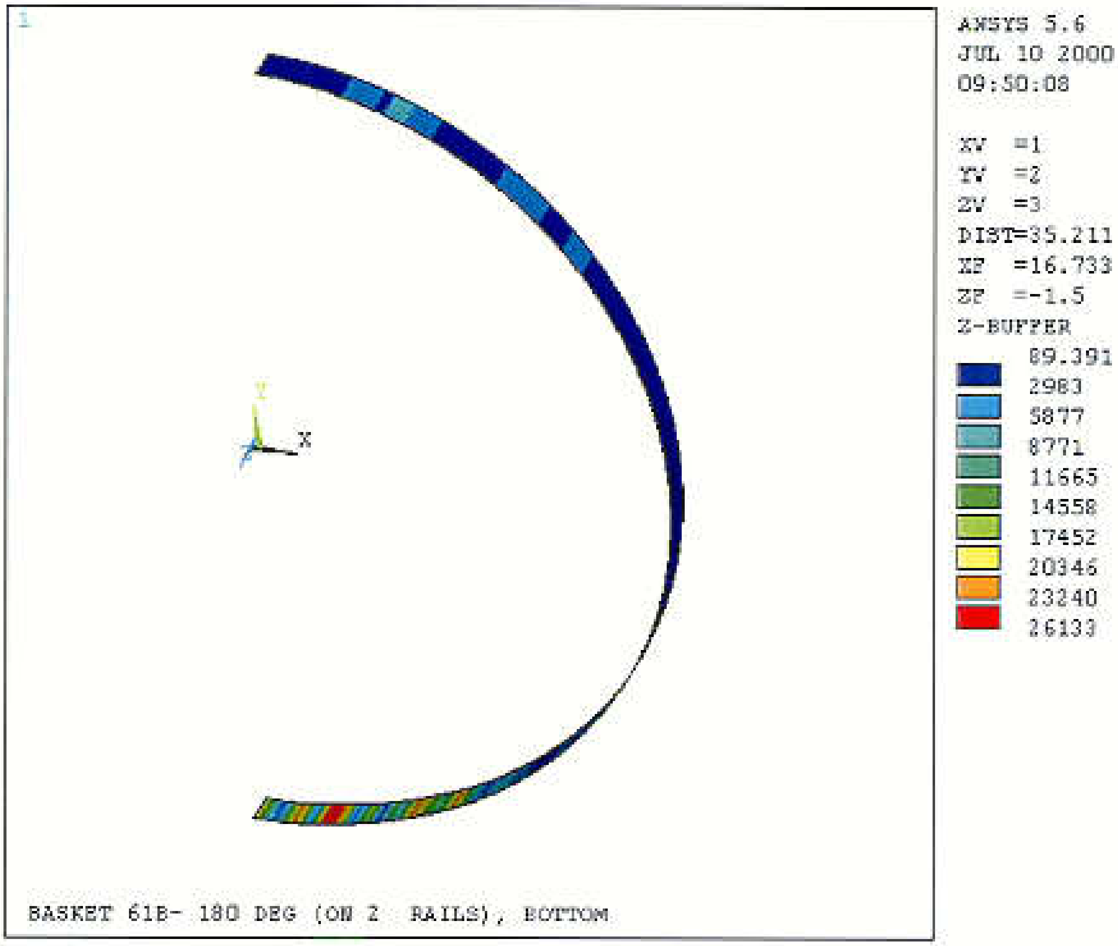

Figure K.3.7-35
180° Orientation Side Drop – Canister, $P_m + P_b$ (75.5g)

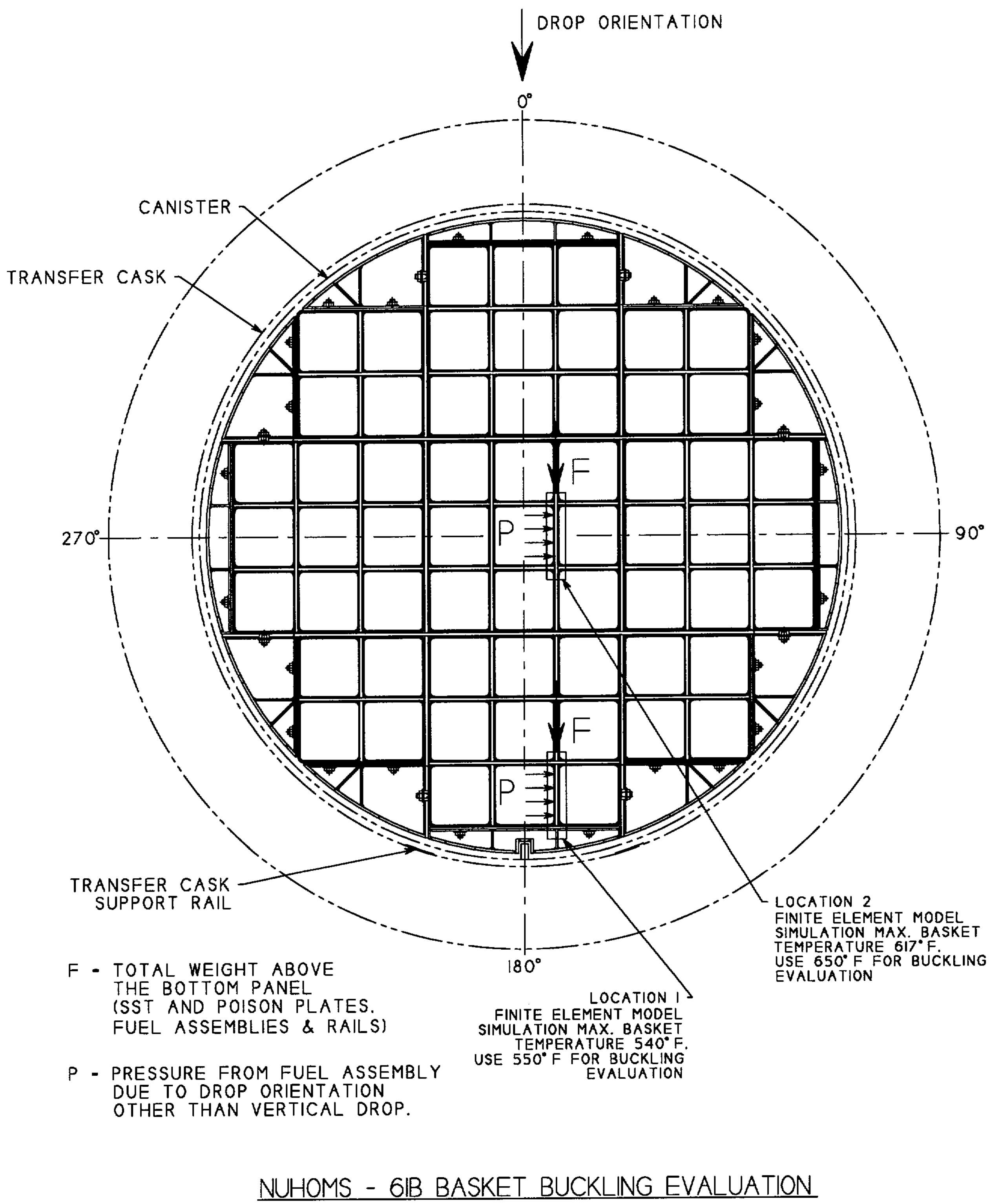

Figure K.3.7-36
NUHOMS 61B Basket Buckling Evaluation

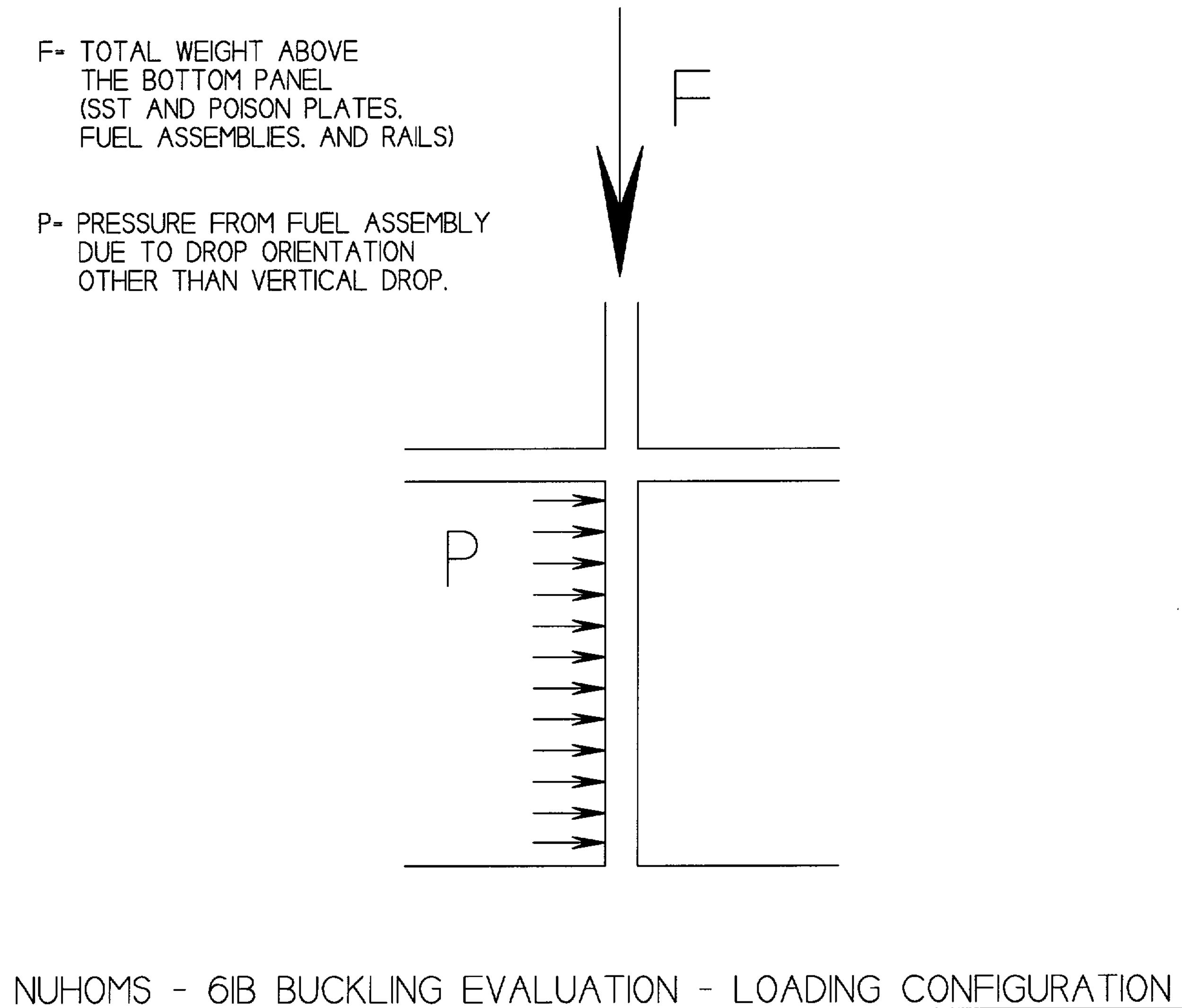

Figure K.3.7-37
NUHOMS 61B Basket Model Geometry

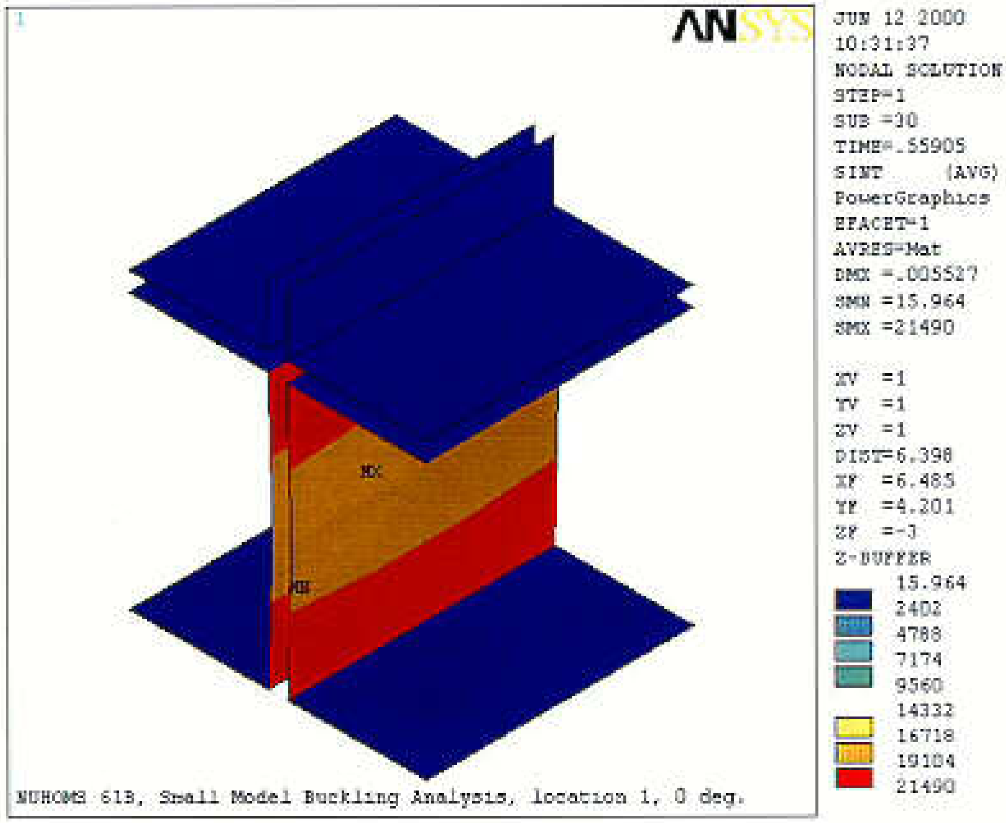

Figure K.3.7-38
Vertical Drop Buckling Analysis, Location 1

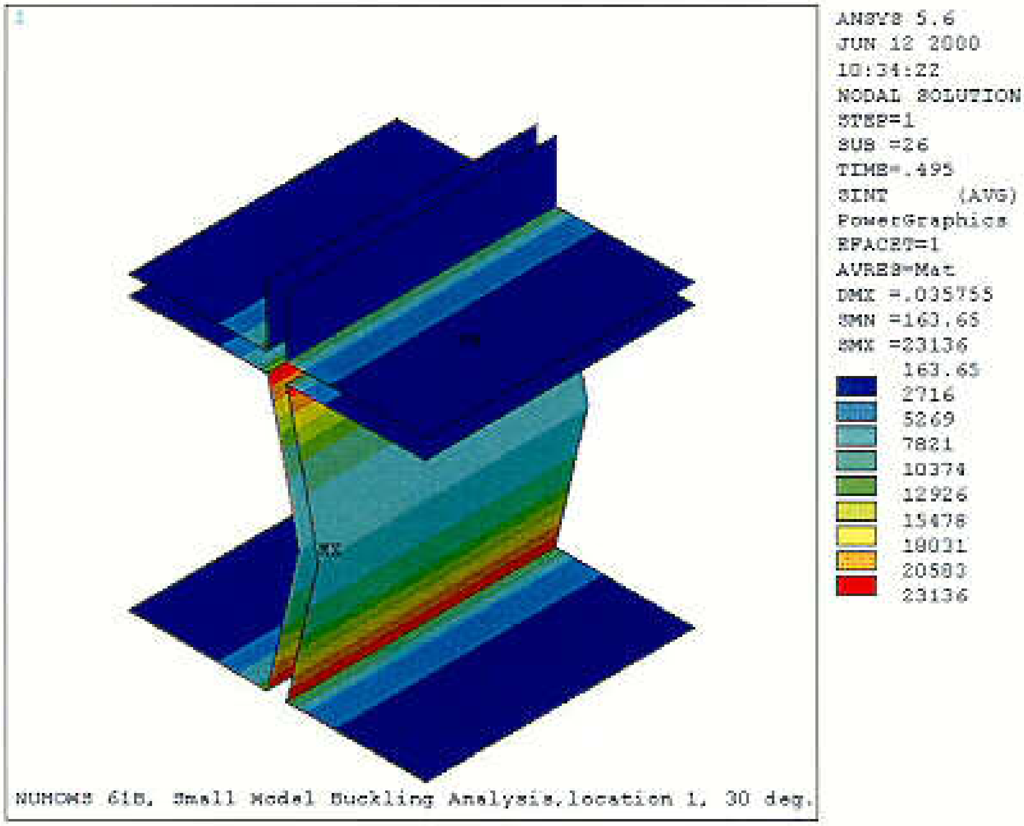

Figure K.3.7-39
30° Drop Buckling Analysis, Location 1

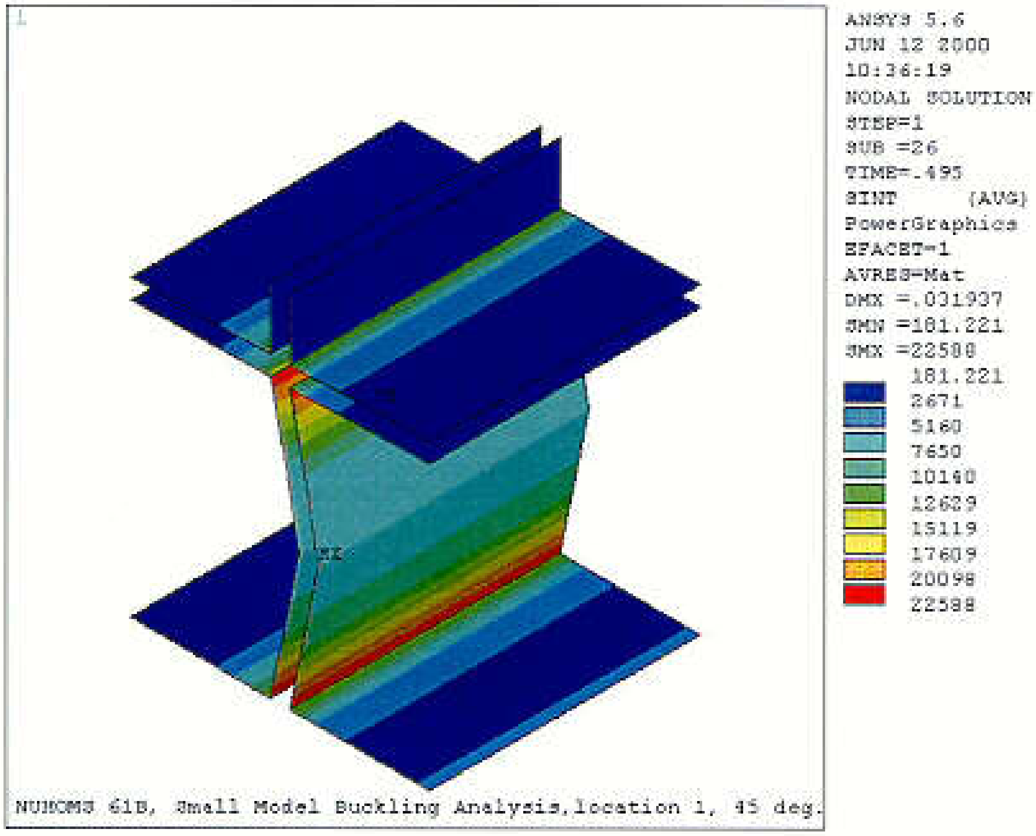

Figure K.3.7-40
45° Drop Buckling Analysis, Location 1

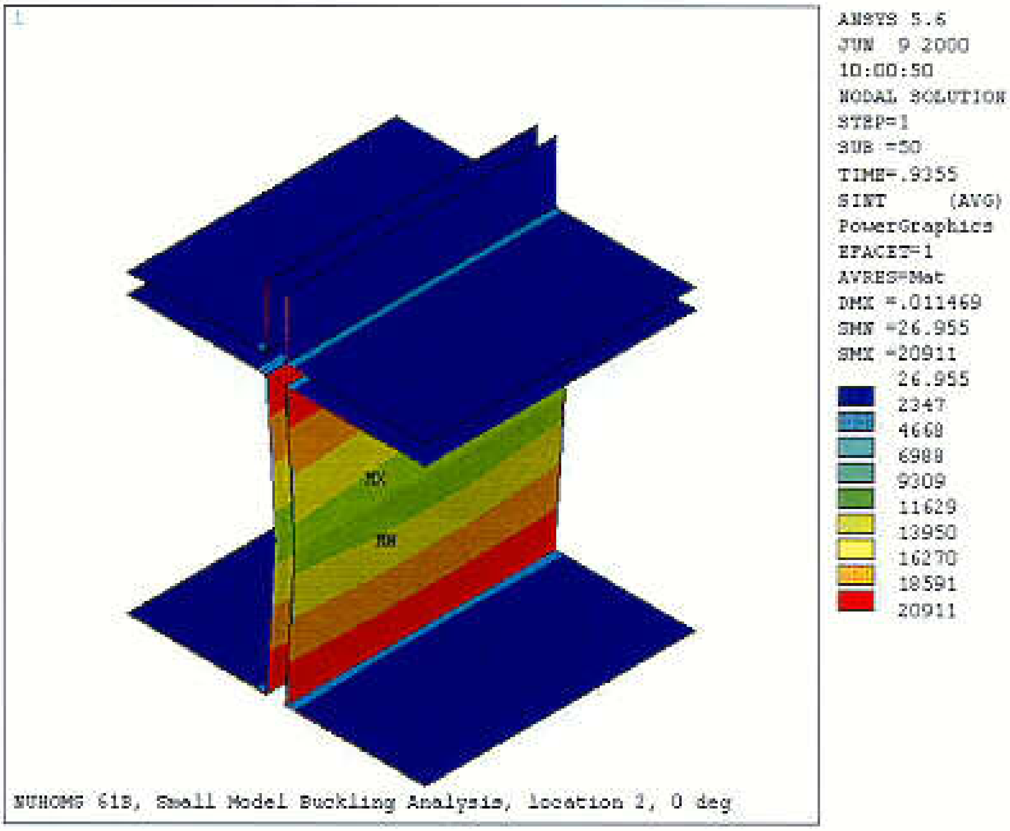

Figure K.3.7-41
Vertical Drop Buckling Analysis, Location 2

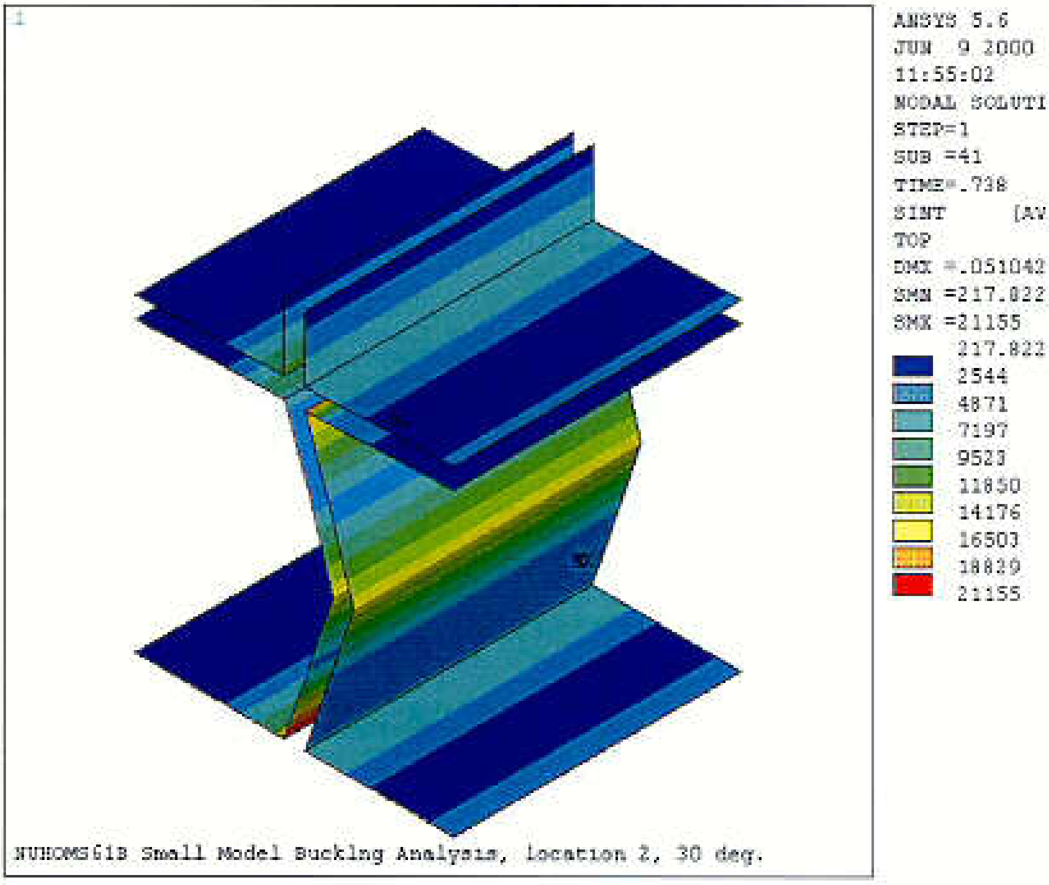

Figure K.3.7-42
30° Drop Buckling Analysis, Location 2

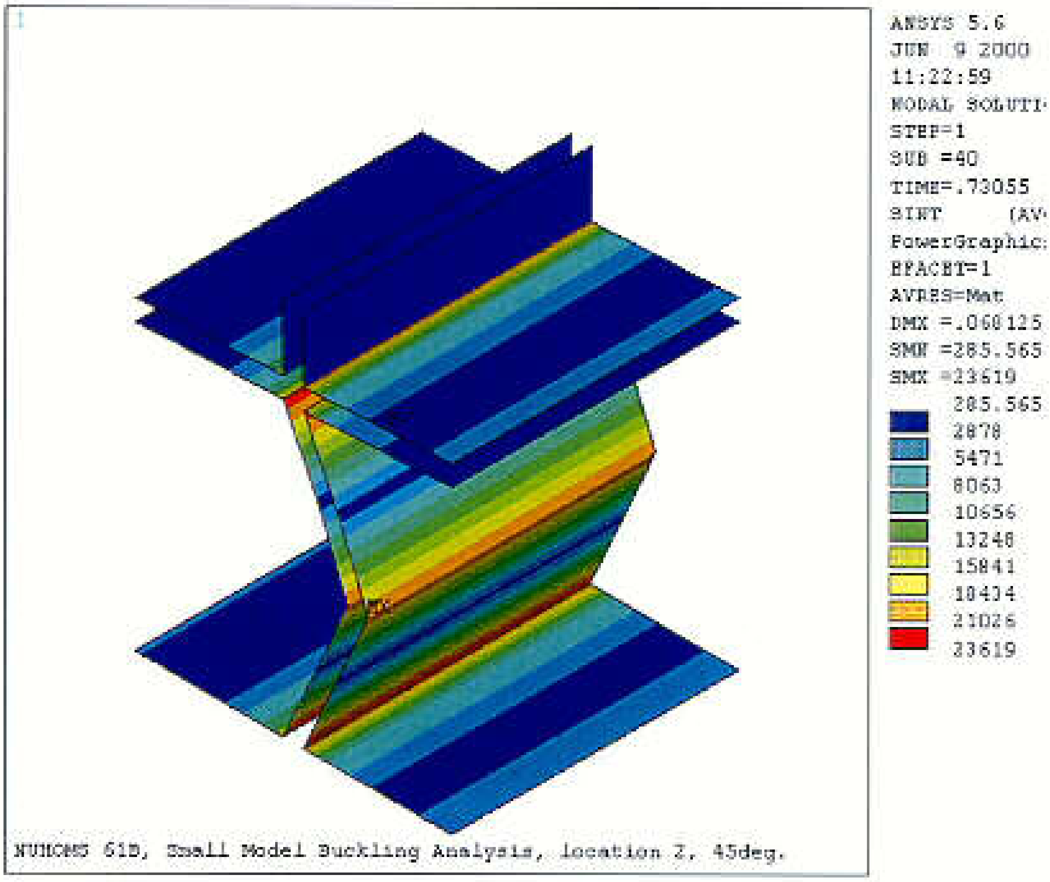

Figure K.3.7-43
45° Drop Buckling Analysis, Location 2

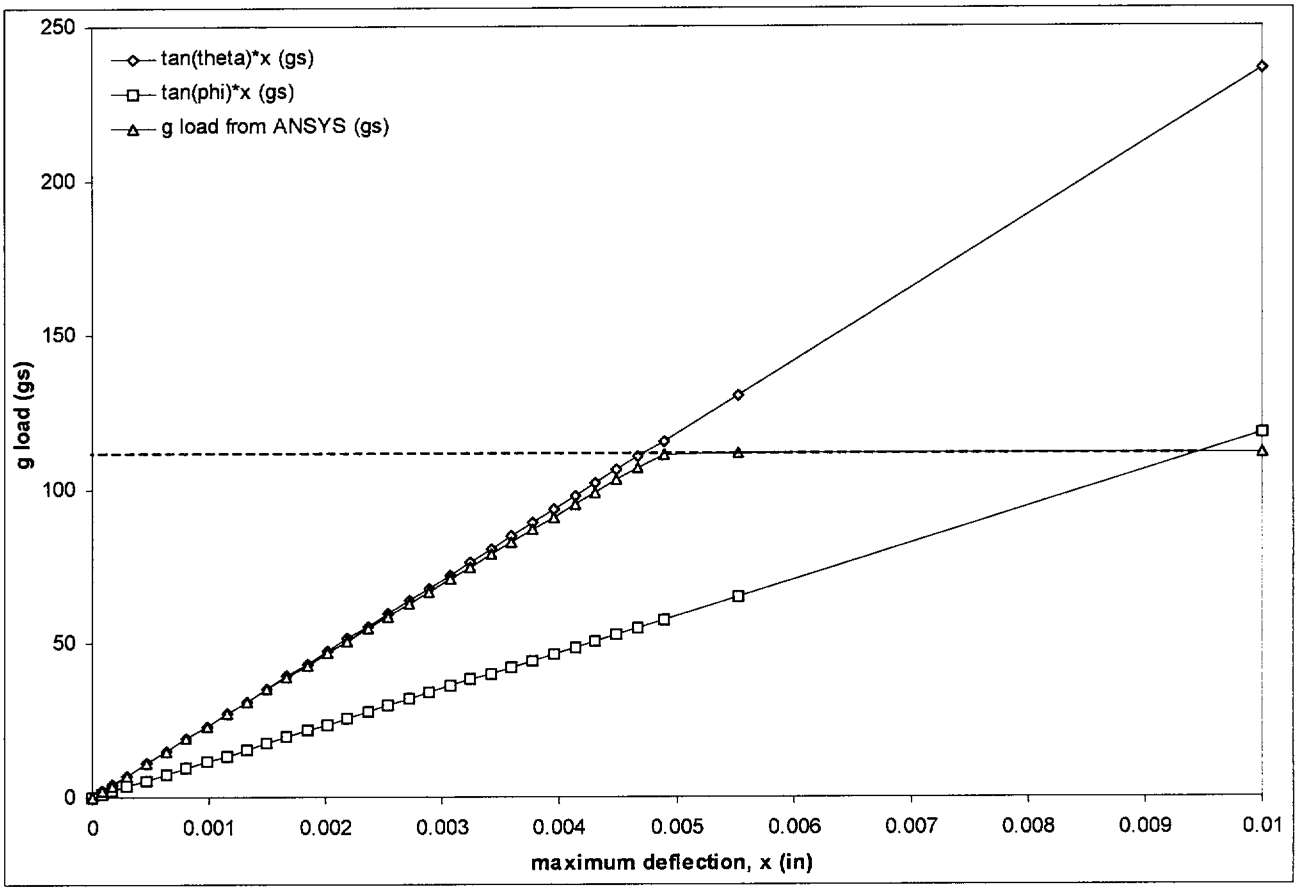

Figure K.3.7-44
Allowable Collapse Load Determination, Location 1, Vertical Drop

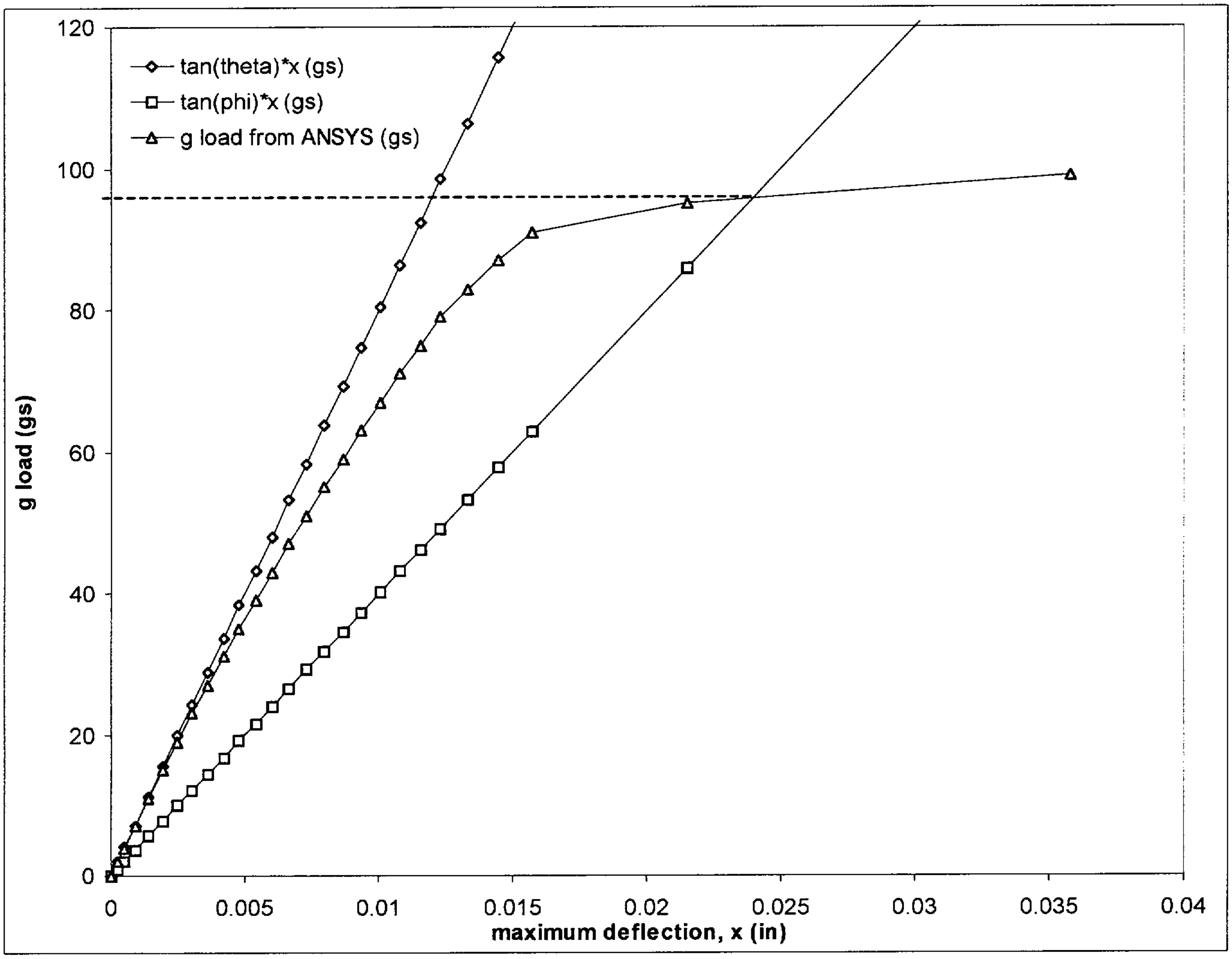

Figure K.3.7-45
Allowable Collapse Load Determination, Location 1, 30° Drop

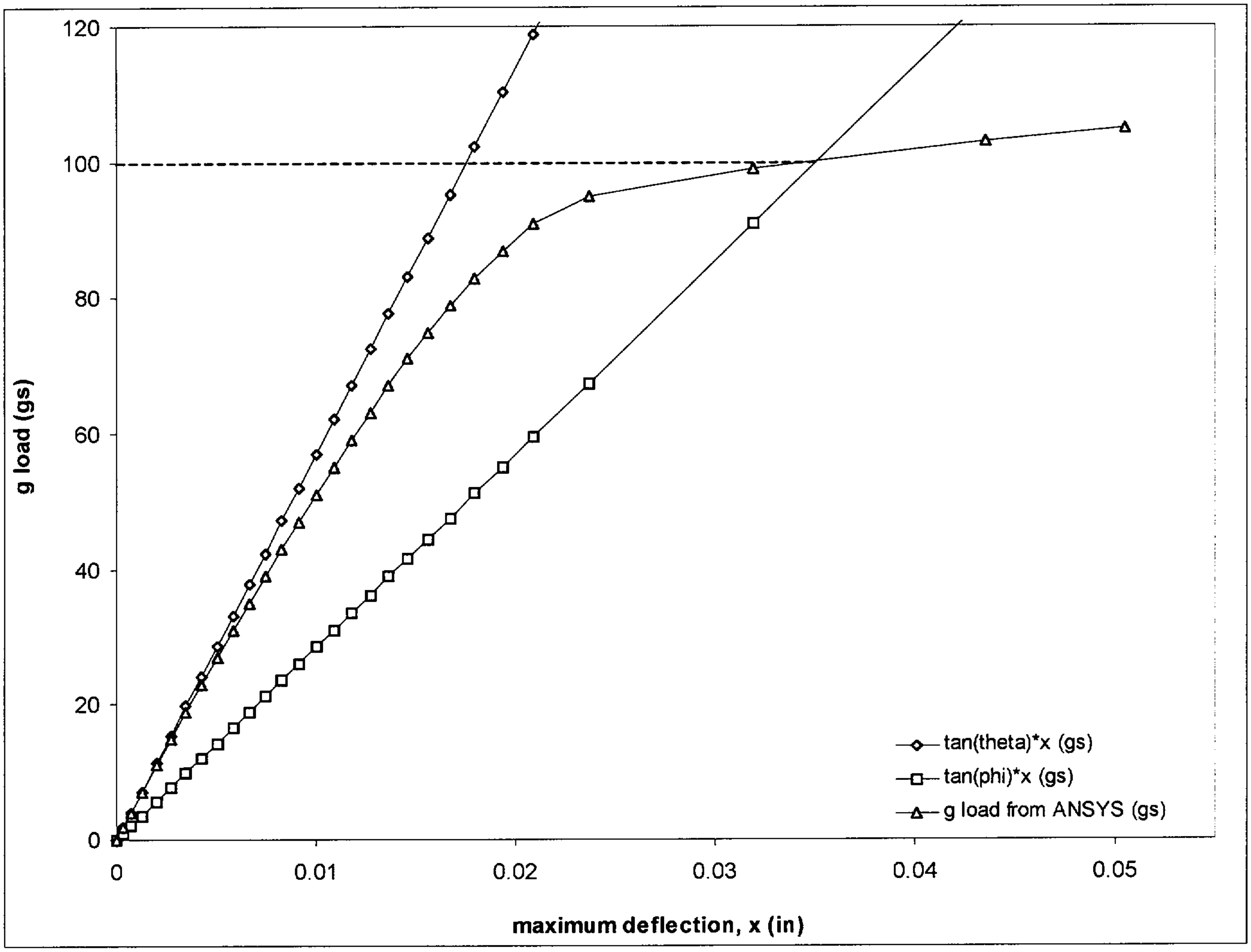

Figure K.3.7-46
Allowable Collapse Load Determination, Location 1, 45° Drop

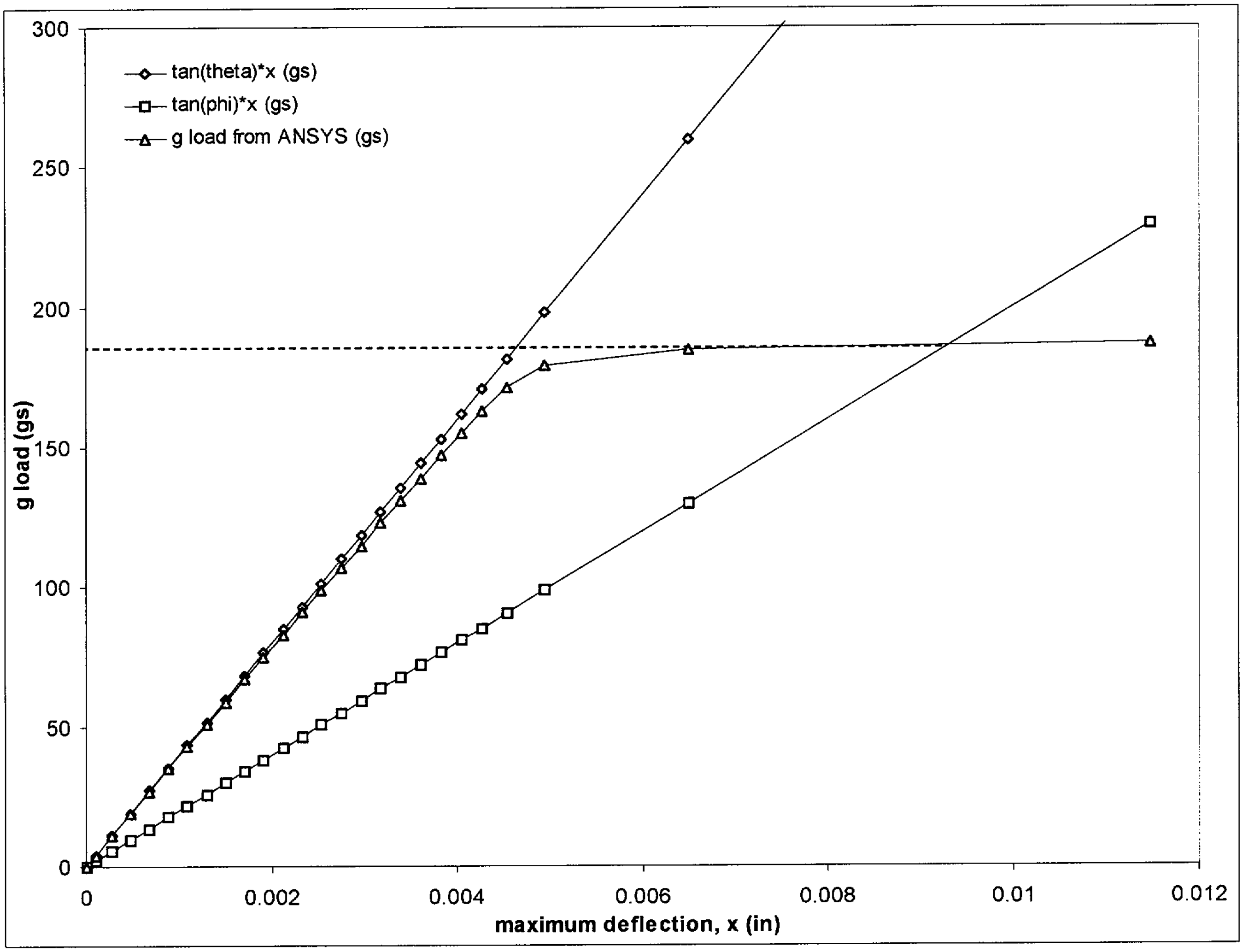

Figure K.3.7-47
Allowable Collapse Load Determination, Location 2, Vertical Drop

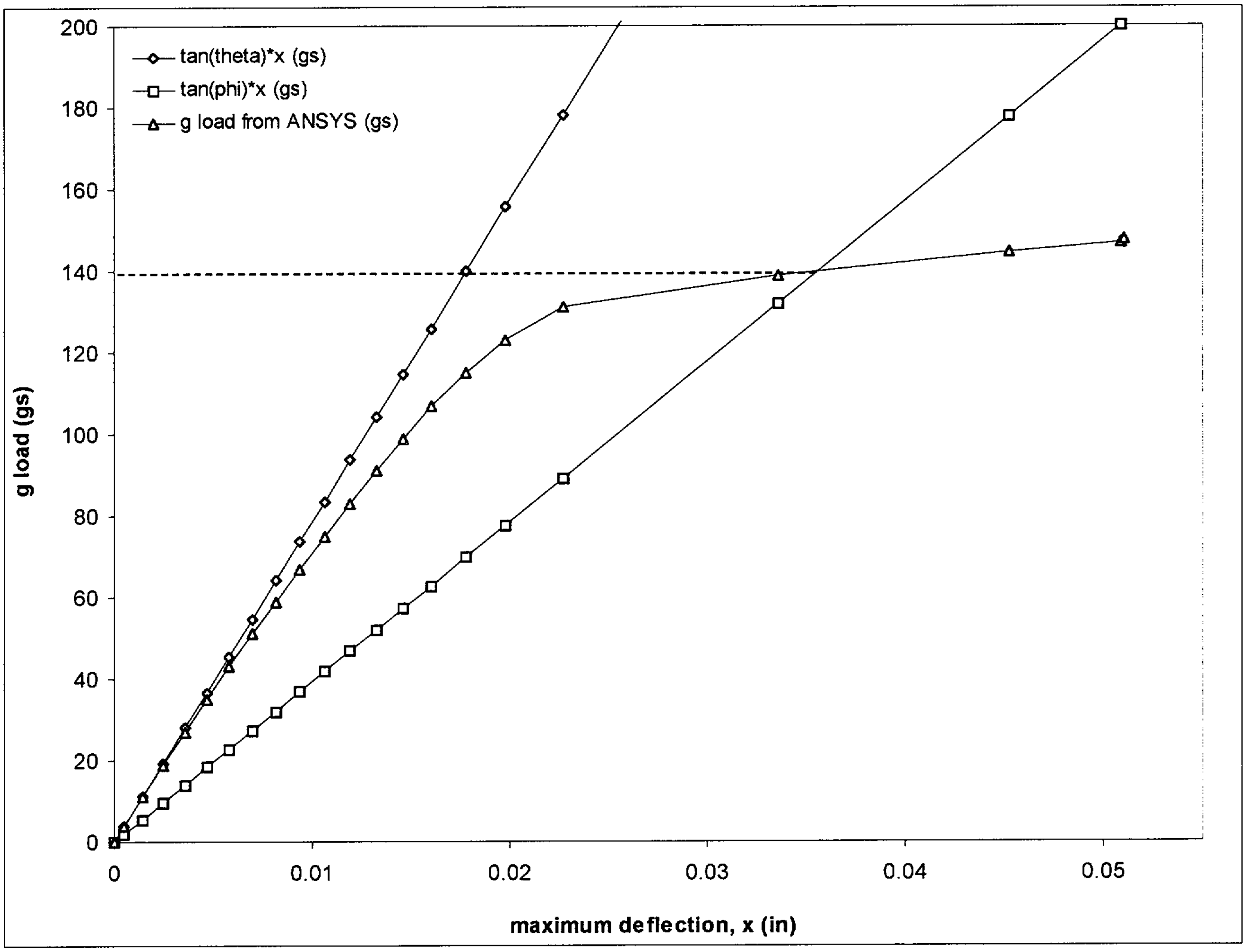

Figure K.3.7-48
Allowable Collapse Load Determination, Location 2, 30° Drop

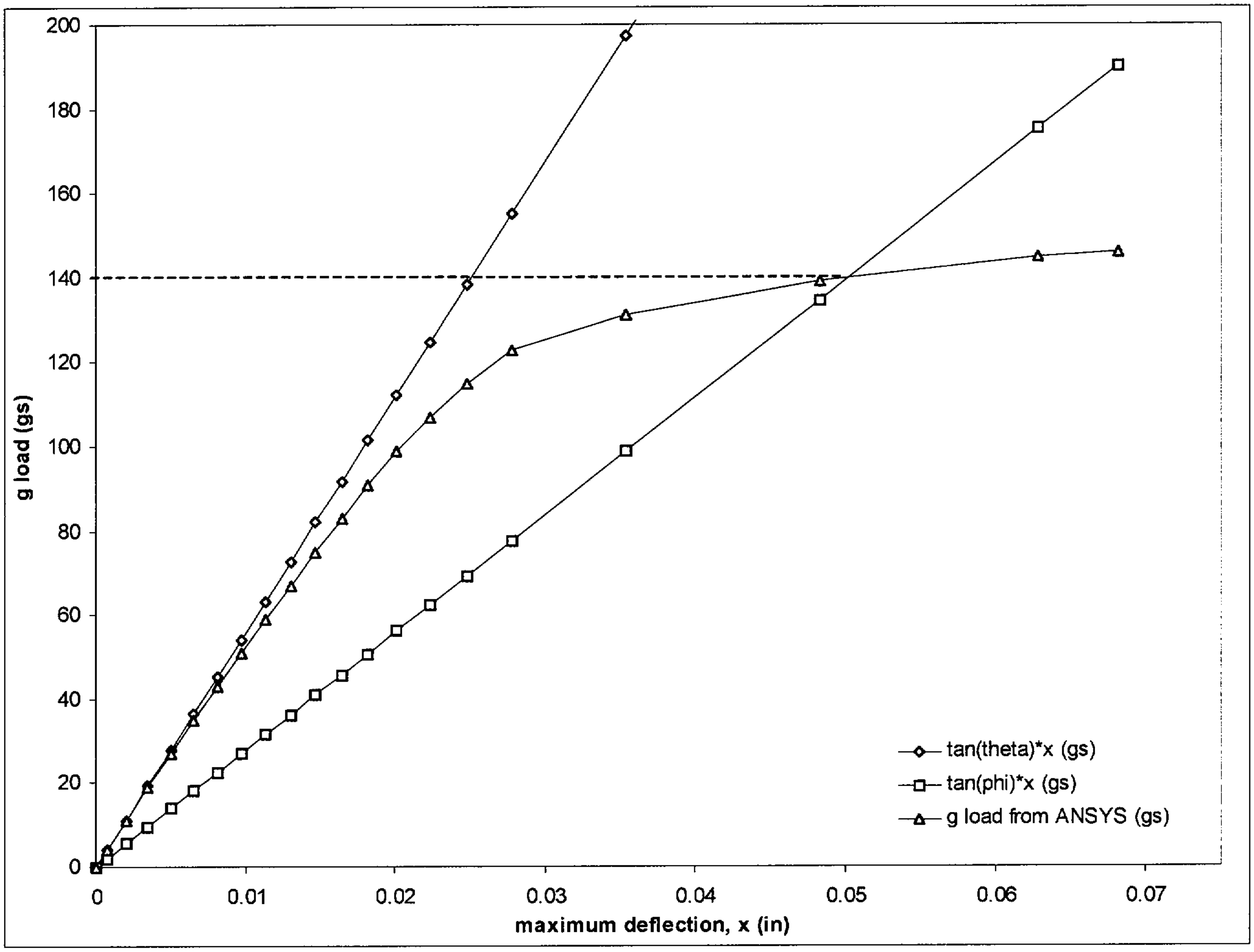

Figure K.3.7-49
Allowable Collapse Load Determination, Location 2, 45° Drop

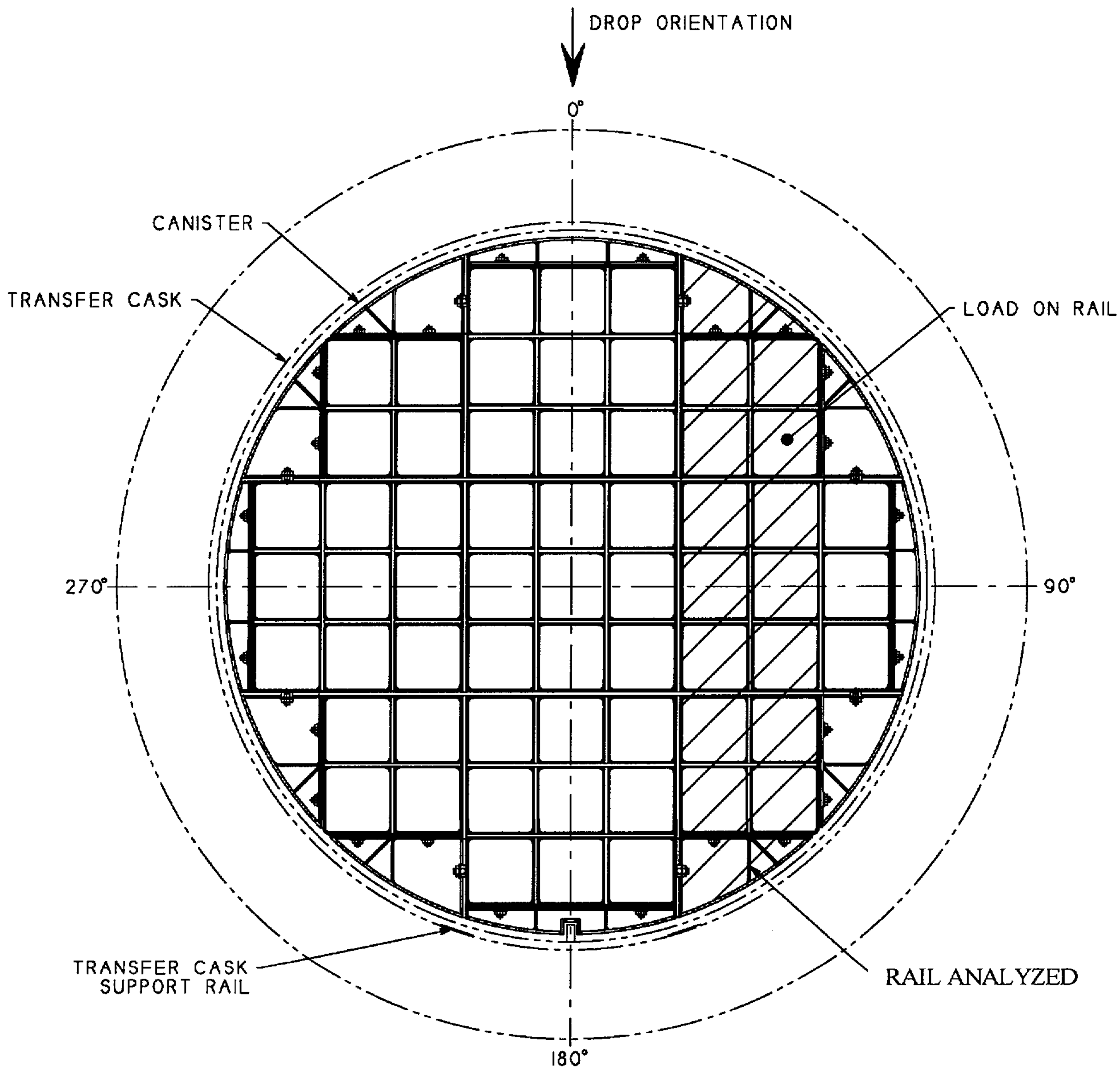

Figure K.3.7-50
NUHOMS 61B Basket Rail Buckling Evaluation

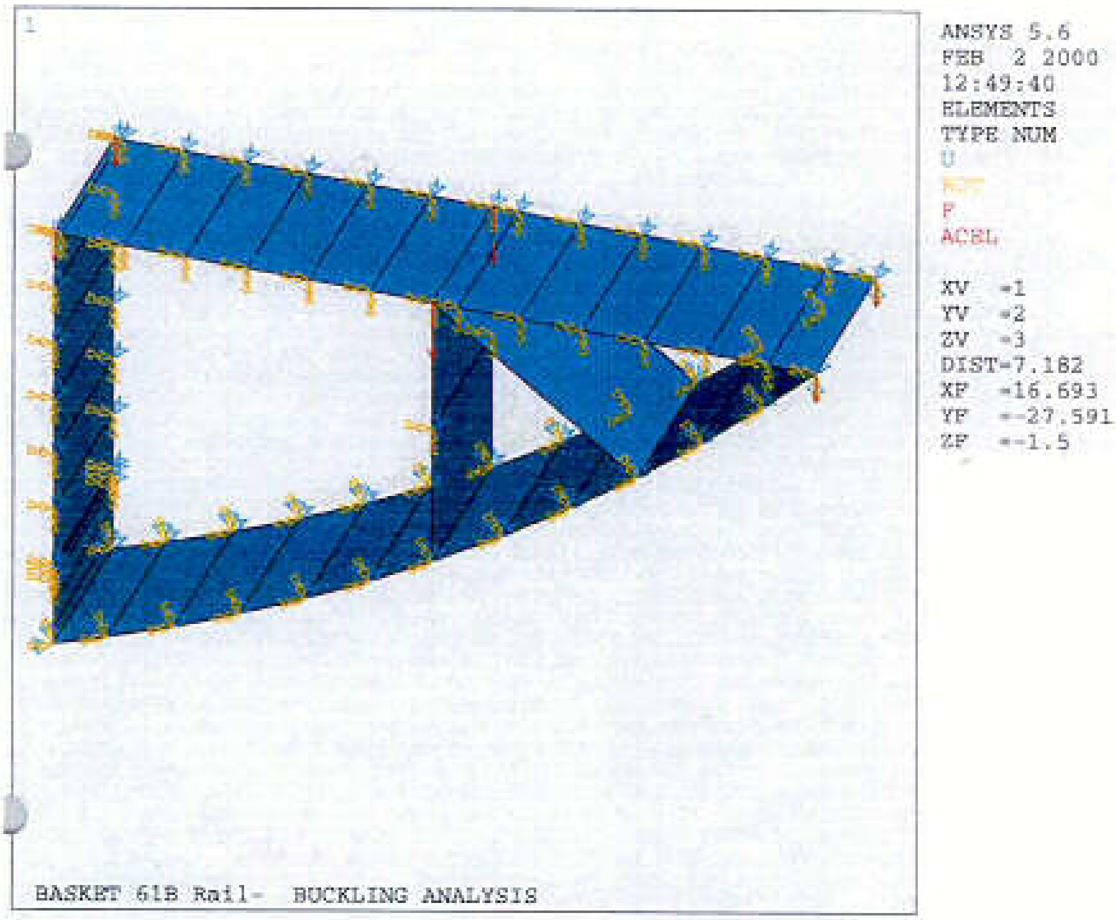

Figure K.3.7-51
NUHOMS 61B Basket Rail Model and Boundary Conditions

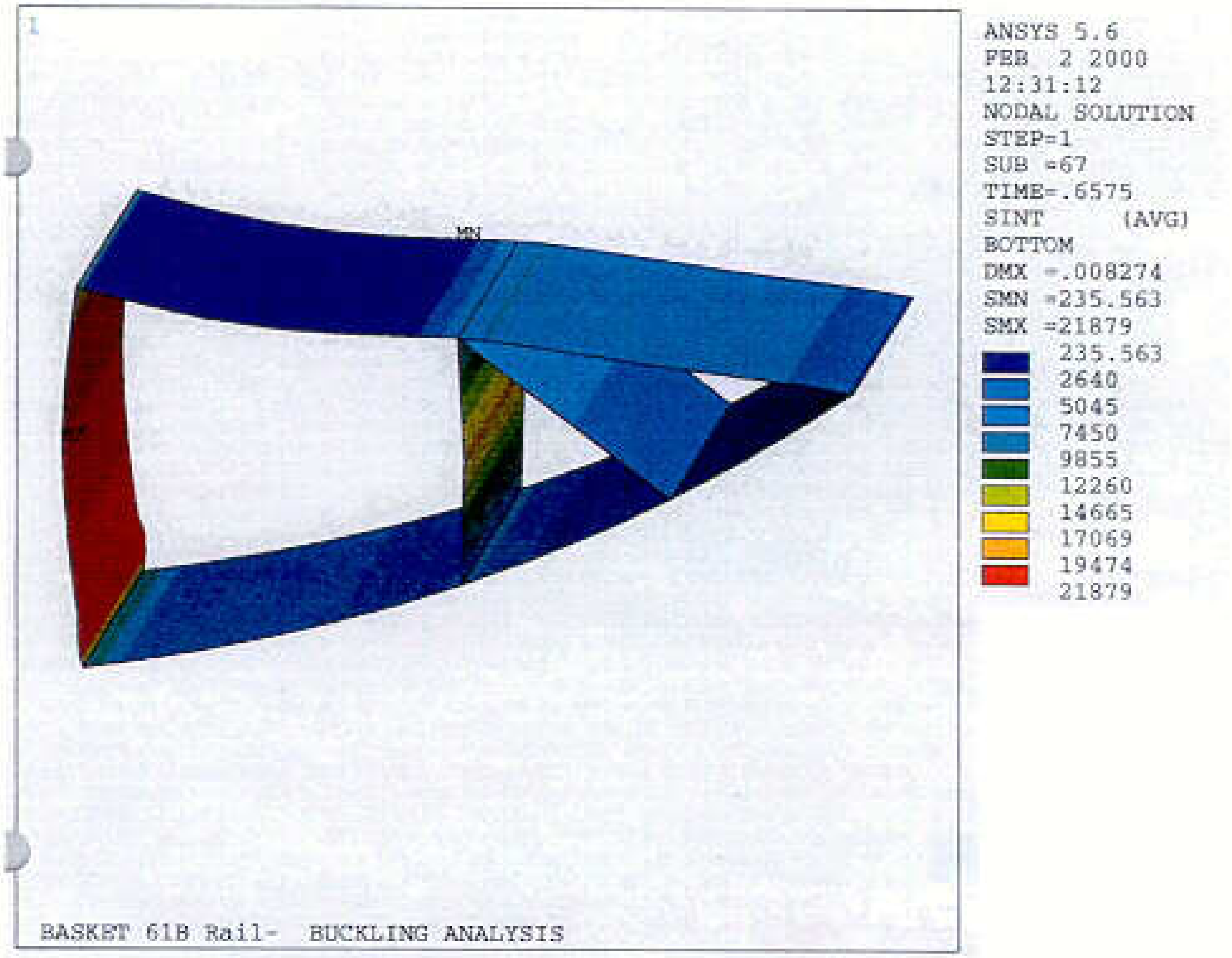

Figure K.3.7-52
NUHOMS 61B Basket Rail Buckling Analysis, Case 1

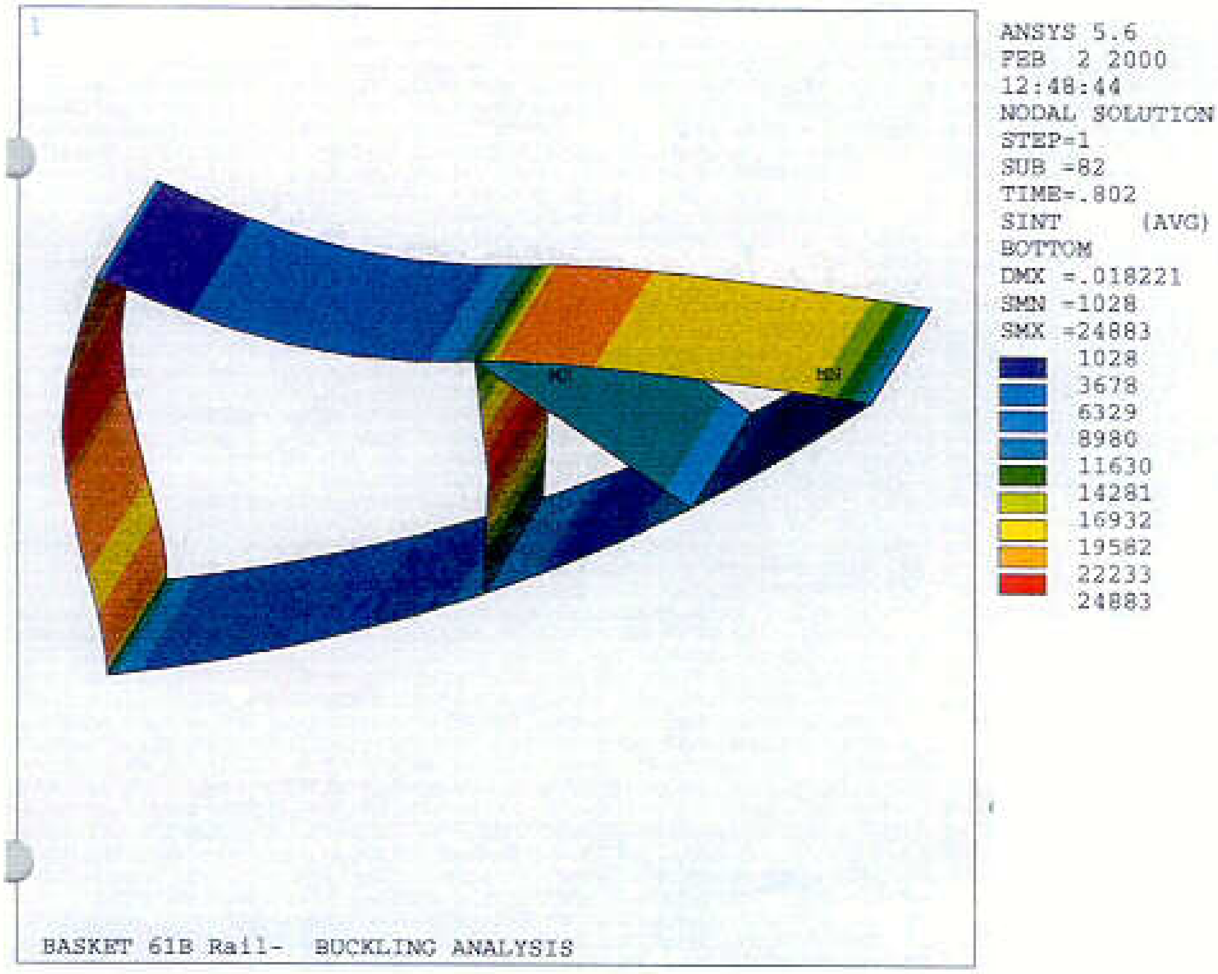

Figure K.3.7-53
NUHOMS 61B Basket Rail Buckling Analysis, Case 2

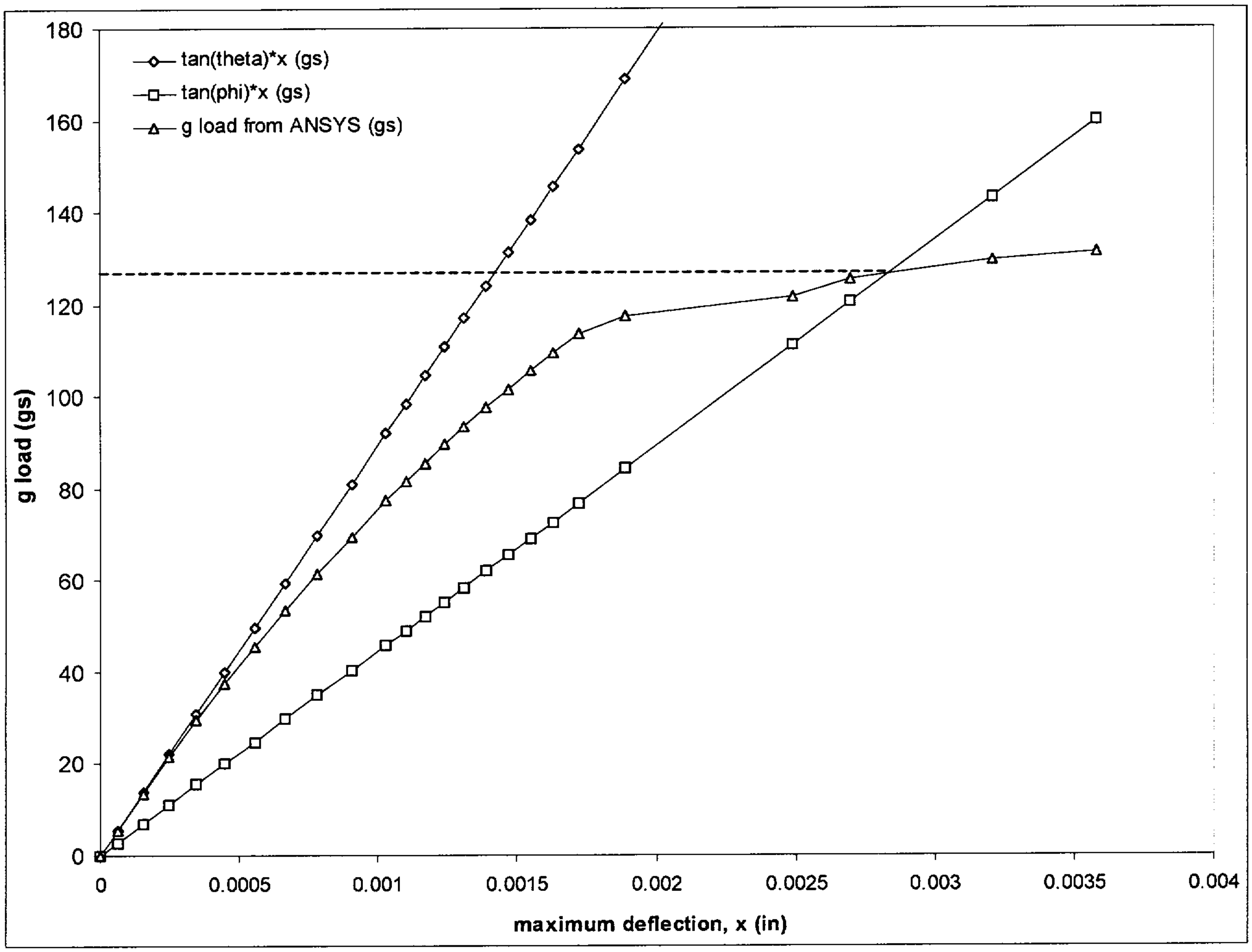

Figure K.3.7-54
Allowable Collapse Load Determination for Basket Rail

K.3.8 References

3.1 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Subsections NB, NC, NF, NG, and Appendices 1998 with 1999 Addenda.

3.2 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Part D, 1998 with 1999 Addenda.

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3.5 Pacific Northwest Laboratory Annual Report – FY 1979, "Spent Fuel and Fuel Pool Component Integrity," May 1980.

3.6 G. Wranglen, "An Introduction to Corrosion and Protection of Metals," Chapman and Hall, 1985, pp. 109-112.

3.7 A.J. McEvily, Jr., ed., "Atlas of Stress Corrosion and Corrosion Fatigue Curves," ASM Int'l, 1995, p. 185.

3.8 Baratta, et al. "Evaluation of Dimensional Stability and Corrosion Resistance of Borated Aluminum," Final Report submitted to Eagle-Pitcher Industries, Inc. by the Nuclear Engineering Department, Pennsylvania State University.

3.9 TNW letter 31-B9604-97-003 dated December 19, 1997 from Dave Dawson to Tim McGinty, NRC.

3.10 "Hydrogen Generation Analysis Report for TN-68 Cask Materials," Test Report No. 61123-99N, Rev. 0, Oct 23, 1998, National Technical Systems.

3.11 ANSYS Engineering Analysis System, Users Manual for ANSYS Rev. 5.6, Swanson Analysis Systems, Inc., Houston, PA, 1998.

3.12 Roark, 4th Edition, "Formulas for Stress and Strain".

3.13 U.S. Nuclear Regulatory Commission (U.S. NRC), "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation (Dry Storage)," Regulatory Guide 3.48 (Task FP-029-4), (October 1981).

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3.15 U.S. Atomic Energy Commission, "Damping Values for Seismic Design of Nuclear Power Plants," Regulatory Guide 1.61, (October 1973).

3.16 R. D. Blevins, "Formulas for Natural Frequency and Mode Shape," Van Nostrand Reinhold Co., New York, N.Y., (1979).

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3.18 Manual of Steel Construction, 8th Edition, 1980.

K.4 Thermal Evaluation

K.4.1 Discussion

The NUHOMS®-61BT System is designed to passively reject decay heat during storage and transfer for normal, off-normal and accident conditions while maintaining temperatures and pressures within specified regulatory limits. Objectives of the thermal analyses performed for this evaluation include:

- Determination of maximum and minimum temperatures with respect to materials limits to ensure components perform their intended safety functions,
- Determination of temperature distributions for the NUHOMS®-61BT DSC components to support the calculation of thermal stresses for the structural components,
- Determination of maximum internal NUHOMS®-61BT DSC pressures for the normal, off-normal and accident conditions,
- Determination of the maximum fuel cladding temperature, and to confirm that this temperature will remain sufficiently low to prevent unacceptable degradation of the fuel during storage.

The NUHOMS®-61BT DSC falls under the jurisdiction of 10CFR Part 72 when used as a component of an ISFSI. To establish the heat removal capability, several thermal design criteria are established for the basket. These are:

- Maximum temperatures of the confinement structural components must not adversely affect the confinement function.
- The maximum initial storage fuel cladding temperature is determined as a function of the initial fuel age using the guidelines provided by the Commercial Spent Fuel Management Program [4.1]. The temperature threshold accounts for the effects of cladding temperature, decay time, burnup and fission gas build-up at 40 GWD/MTU. Waterside corrosion of 0.002 in. (radially) has been assumed. For normal conditions of storage, a fuel temperature limit of 343°C (649°F) has been established. During loading/unloading, transfer and accident conditions, the fuel temperature limit is 570°C (1058°F) [4.9].
- The maximum DSC cavity internal pressures during normal, off-normal and accident conditions must be below the design pressures of 10 psig, 20 psig and 65 psig, respectively.

The NUHOMS®-61BT DSC is analyzed based on a maximum heat load of 18.3 kW from 61 BWR fuel assemblies. The analyses consider the effect of the decay heat flux varying axially along a fuel assembly. The axial heat flux profile for a BWR fuel assembly shown in Figure K.4-8 and an active length of 144 in. is used for the evaluation. The use of these parameters bounds the peak heat flux for the design basis fuel. A description of the detailed analyses performed for normal storage conditions is provided in Section K.4.4, off-normal conditions in Section K.4.5, accident conditions in Section K.4.6, and loading/unloading conditions in Section K.4.7. The thermal evaluation concludes that with a design basis heat load of 18.3 kW, all design criteria are satisfied.

K.4.2 Summary of Thermal Properties of Materials

1. BWR Fuel with Helium Backfill [4.7]

Temperature (°F)	Thermal Conductivity (Btu/hr-in-°F)	
	Transverse	Axial
116.8	0.0137	0.0437
214.4	0.0160	...
312.4	0.0186	...
410.7	0.0215	...
509.3	0.0249	...
608.0	0.0288	0.0437

The effective thermal conductivity is the lowest calculated value for the BWR fuel array that may be stored in this cask and corresponds to the GE 10x10 BWR assembly with channels.

2. BWR Fuel w/ Air Backfill [4.7]

Temperature (°F)	Thermal Conductivity (Btu/hr-in-°F)	
	Transverse	Axial
150.8	0.0045	0.0437
240.0	0.0058	...
331.6	0.0073	...
425.1	0.0092	...
520.1	0.0114	...
616.3	0.0141	...
900.0	0.0221*	0.0437

* Determined via linear extrapolation

3. Air [4.2]

Temperature (°F)	Thermal Conductivity (Btu/hr-in-°F)
-100	0.0009
80	0.0013
260	0.0016
440	0.0019
620	0.0022
980	0.0028
1340	0.0033

4. SA-240, Type 304 Stainless Steel [4.3]

Temperature (°F)	α (ft²/hr)	ρ (lbm/in³)	Thermal Conductivity (Btu/hr-in-°F)	C_p (Btu/lbm-°F)
70	0.151	0.282	0.717	0.117
100	0.152	...	0.725	0.117
150	0.154	...	0.750	0.120
200	0.156	...	0.775	0.122
250	0.158	...	0.800	0.125
300	0.160	...	0.817	0.126
350	0.162	...	0.842	0.128
400	0.165	...	0.867	0.129
450	0.167	...	0.883	0.130
500	0.170	...	0.908	0.131
550	0.172	...	0.925	0.132
600	0.174	...	0.942	0.133
650	0.177	...	0.967	0.134
700	0.179	...	0.983	0.135
750	0.181	...	1.000	0.136
800	0.184	...	1.017	0.136
850	0.186	...	1.042	0.138
900	0.189	...	1.058	0.138
950	0.191	...	1.075	0.138
1000	0.194	0.282	1.100	0.139

5. Helium [4.2].

Temperature (°F)	Thermal Conductivity (Btu/hr-in-°F)
-280	0.0004
-190	0.0005
-100	0.0055
-10	0.0064
80	0.0072
260	0.0087
440	0.0102
620	0.0119
980	0.0148
1340	0.0175

6. SA-36 Carbon Steel [4.3]

Temperature (°F)	α (ft²/hr)	ρ (lbm/in³)	Thermal Conductivity (Btu/hr-in-°F)	C_p (Btu/lbm-°F)
70	0.529	0.282	2.292	0.107
100	0.512	...	2.300	0.110
150	0.496	...	2.300	0.114
200	0.486	...	2.300	0.116
250	0.467	...	2.283	0.120
300	0.453	...	2.267	0.123
350	0.440	...	2.250	0.126
400	0.428	...	2.225	0.128
450	0.413	...	2.192	0.130
500	0.398	...	2.158	0.133
550	0.387	...	2.125	0.135
600	0.374	...	2.083	0.137
650	0.360	...	2.042	0.139
700	0.346	...	2.000	0.142
750	0.332	...	1.958	0.145
800	0.318	...	1.917	0.148
850	0.305	...	1.883	0.152
900	0.291	...	1.842	0.156
950	0.277	...	1.792	0.159
1000	0.263	0.282	1.750	0.164

7. 6063 Aluminum [4.3]

Temperature (°F)	α (ft²/hr)	ρ (lbm/in³)	Thermal Conductivity (Btu/hr-in-°F)	C_p (Btu/lbm-°F)
70	3.34	0.097	10.067	0.216
100	3.30	...	10.025	0.217
150	3.23	...	9.975	0.221
200	3.18	...	9.925	0.223
250	3.13	...	9.858	0.225
300	3.09	...	9.858	0.228
350	3.04	...	9.825	0.231
400*	3.00	0.097	9.800	0.234

**For temperatures greater than 400°F, the values at 400°F are used.*

8. Poison Plates [4.2]

C_p (Btu/lbm-°F)	ρ (lbm/in³)
0.214	0.098

The analyses use interpolated values when appropriate for intermediate temperatures. The interpolation assumes a linear relationship between the reported values.

Thermal radiation effects on the interior surfaces of the basket rails are considered. The emissivity of unfinished stainless steel is 0.587 [4.4]. For additional conservatism an emissivity of 0.500 is used within the analysis.

K.4.3 Specifications for Components

The thermal conductivity of the neutron poison plates will be verified by testing. The neutron poison plates will have the following minimum conductivity:

Temperature (°F)	Thermal Conductivity (Btu/hr-in-°F)
68	5.78
212	6.98
482	7.22
571	7.22
600	7.22
650	7.22

The thermal conductivity values [4.7] for the neutron poison plates specified above will be bounded by test data.

K.4.4 Thermal Evaluation for Normal Conditions of Storage (NCS) and Transfer (NCT)

The normal conditions of storage are used for the determination of the maximum fuel cladding temperature, component temperatures, NUHOMS®-61BT DSC internal pressure and thermal stresses. These steady state conditions are an ambient temperature of 100 °F and the 10CFR Part 71.71(c) insolation averaged over a 24-hour period.

K.4.4.1 NUHOMS®-61BT DSC Thermal Models

The NUHOMS®-61BT DSC finite element models are developed using the ANSYS computer code [4.5]. ANSYS is a comprehensive thermal, structural and fluid flow analysis package. It is a finite element analysis code capable of solving steady state and transient thermal analysis problems in one, two or three dimensions. Heat transfer via a combination of conduction, radiation and convection can be modeled by ANSYS. The three-dimensional geometry of the DSC was modeled. Solid entities were modeled by SOLID70 three-dimensional thermal elements. Radiation within the basket rails was modeled by MATRIX50 super elements.

The three-dimensional models represents 90° and 180° symmetric sections of the NUHOMS®-61BT DSC, and include the geometry and material properties of the basket components, the basket rails, and DSC. The model simulates the effective thermal properties of the fuel with a homogenized material occupying the volume within the basket where the 144 inch active length of the fuel is stored. The finite element plot of the 90° model is shown in Figure K.4-5.

Generally, good surface contact is expected between adjacent components within the basket structure. However to bound the heat conductance uncertainty between adjacent components, conservative gaps between the adjacent components have been included in the model. All heat transfer across the gaps is by gaseous conduction. Other modes of heat transfer are conservatively neglected.

Boundary Conditions, Storage

Analyses of the NUHOMS®-52B DSC within the HSM have been previously performed [4.8] for the following ambient conditions:

- Maximum normal ambient temperature of 100 °F with insolation. This case bounds the lifetime average ambient temperature of 70°F for 50 years service life.
- Minimum off-normal extreme ambient temperature of -40 °F without insolation. This case bounds the 0°F minimum normal (winter) average ambient temperature.
- Maximum off-normal extreme ambient temperature of 125 °F with insolation.
- Blocked vent accident condition concurrent with off-normal extreme ambient temperature of 125 °F with insolation.

These analyses for the NUHOMS®-52B DSC, which use a total decay heat load of 19.2 kW, determine temperature distributions for the NUHOMS®-52B DSC that bound those for the NUHOMS®-61BT with its lower decay heat load of 18.3 kW. These temperature distributions, shown in Figure K.4-1 through Figure K.4-4, are applied as boundary conditions to the finite element models for normal, off-normal, and accident conditions of storage.

Boundary Conditions, Transfer

Analyses of the NUHOMS®-61BT DSC within the OS197 transfer cask is performed for the following ambient conditions:

- Maximum normal ambient temperature of 100 °F with insolation
- Minimum off-normal extreme ambient temperature of -40 °F without insolation
- Vacuum Drying under an ambient of 100 °F without insolation

These analyses, which use a total decay heat load of 18.3 kW per DSC, determine maximum temperatures within the DSC of 378 °F and 308 °F for the maximum normal and minimum off-normal conditions, respectively. A maximum DSC temperature of 369 °F is determined for the vacuum drying condition. These maximum temperatures are conservatively applied to the entire exterior surface of the DSC in the finite element model.

Maximum Fuel Cladding Temperature

The finite element models include a representation of the spent nuclear fuel that is based on a fuel effective conductivity model. The decay heat of the fuel adjusted to account for axial peaking was applied directly to the fuel elements. The maximum fuel temperature reported is based on the results of the temperature distribution in the fuel region of the model. The effective conductivity used in this region is determined in [4.7].

Average Cavity Gas Temperature

For simplicity, the cavity gas temperature is assumed to be the volume averaged temperature of the gaseous elements within the NUHOMS®-61BT DSC models.

Decay Heat Load

The decay heat load is applied as volumetric heat generation in the elements that represent the homogenized fuel. This heat load corresponds to a total heat load of 18.3 kW from 61 BWR assemblies (0.300 kW/assembly). The heat load was adjusted to account for axial peaking. A typical axial heat flux profile for spent BWR fuel was used to distribute the decay heat load in the axial direction within the active length region of the model. This heat flux profile is shown Figure K.4-8.

K.4.4.2 Maximum Temperatures

Steady-state thermal analyses are performed with the 90° symmetry finite element model using the maximum decay heat load of 0.300 kW per assembly (18.3 kW total per DSC) for normal conditions of storage and transfer. A summary of the calculated component temperatures is listed in Table K.4-1 and Table K.4-2.

K.4.4.3 Minimum Temperatures

The off-normal extreme conditions of -40 °F ambient without insolation are used to bound both normal and off-normal minimum temperature distributions. Under the minimum temperature condition of -40°F ambient, the resulting DSC component temperatures will approach -40°F if no credit is taken for the decay heat load. Since the DSC materials, including confinement structures, continue to function at this temperature, the minimum temperature condition has no adverse effect on the performance of the NUHOMS®-61BT DSC.

Steady-state thermal analyses are performed with the 90° symmetry finite element model using the maximum decay heat load of 0.300 kW per assembly (18.3 kW total per DSC) and the minimum ambient condition. A summary of the calculated component temperatures are given in Figure K.4-6 and listed in Table K.4-3.

K.4.4.4 Maximum Internal Pressures

During normal conditions, the internal pressure of the NUHOMS®-61BT DSC is calculated assuming that one percent (1%) of the fuel rods are failed. For determination of internal pressure within the DSC, it is assumed that 100 percent of the rods fill gas, and 30 percent of the significant fission gases within the failed fuel rods are available for release into the DSC cavity [4.6].

Free Gas within Fuel Assemblies

The determination of fission gases within the fuel rods is based on SAS2H / ORIGEN-S computer runs [4.7]. I, Kr, and Xe gases are considered following irradiation. Including the 30 percent release fraction for these gases, the total moles of free gas in each of the fuel assembly types to be stored in the NUHOMS®-61BT DSC are tabulated below:

Fuel Design	**Fill Gas**	**Fission Gas**	**Total**	**Total**
	(kg moles/rod)	(kg moles/rod)	(kg moles/rod)	(lb moles/assy)
7x7-49-0	5.489E-06	6.640E-05	7.189E-05	7.767E-03
8x8-63-1	3.842E-06	4.889E-05	5.273E-05	7.325E-03
8x8-62-2	8.176E-06	4.923E-05	5.741E-05	7.848E-03
8x8-60-4	8.177E-06	5.016E-05	5.834E-05	7.718E-03
8x8-60-1	8.247E-06	5.041E-05	5.866E-05	7.760E-03
9x9-74-2	1.800E-05	3.927E-05	5.727E-05	9.345E-03
10x10-92-2	1.492E-05	3.318E-05	4.810E-05	**9.758E-03**

The bounding case of the General Electric 10x10 fuel assembly is used for the determination of internal pressures.

Initial Helium Fill

The amount of helium present within the DSC is calculated using the ideal gas law and a maximum initial helium fill pressure of 3.5 psig or 1.24 atm. The initial fill temperature of 273°F is conservative and corresponds to the cavity gas temperature for the –40°F ambient case in Table K.4-3.

$$n = \frac{PV}{RT}$$

P = initial DSC fill pressure = 1.24 atm
V = DSC internal free volume = 214.86 ft^3
T = initial fill temperature = 733 °R
R = universal gas constant = 0.730 atm-ft^3/lbmole-°R

$$n = \frac{(214.86)(1.24)}{(0.730)(733)} = 0.498 \text{ lb moles}$$

Maximum Internal Pressures During Storage and Transfer

The average cavity gas temperature during normal conditions of storage and transfer are 403 °F and 480 °F (863 and 940 °R), respectively as shown in Table K.4-1 and Table K.4-2. With rupture of one percent of the fuel rods, the pressures within the DSC are calculated via the ideal gas law:

$$P_{storage} = \frac{nRT}{V} = \frac{(0.498 + (61)(0.01)(9.758E-3))(0.730)(863)}{214.86} = 1.48 \text{ atm (7.0 psig)}$$

$$P_{transfer} = \frac{nRT}{V} = \frac{(0.498 + (61)(0.01)(9.758E-3))(0.730)(940)}{214.86} = 1.61 \text{ atm (9.0 psig)}$$

K.4.4.5 Maximum Thermal Stresses

The maximum thermal stresses during normal conditions of storage and transfer are calculated in section K.3.

K.4.4.6 Evaluation of Cask Performance for Normal Conditions

The temperatures in the NUHOMS® HSM and transfer cask are bounded by the existing analysis in the CSAR because of higher heat load for the NUHOMS®-24P or NUHOMS®-52B design. The NUHOMS®-61BT DSC shell and basket are evaluated for the calculated temperatures and pressures in Section K.3. The maximum fuel cladding temperatures are well below the allowable fuel temperature limit of 649°F (343°C). The pressure remains below 10.0 psig during normal conditions of storage and transfer. Based on the thermal analysis, it is concluded that the NUHOMS®-61BT DSC design meets all applicable thermal requirements.

K.4.5 Thermal Evaluation for Off-Normal Conditions

The NUHOMS®-61BT system components are evaluated for the extreme ambient temperatures of –40 °F (winter) and 125 °F (summer). Should these extreme temperatures ever occur, they would be expected to last for a very short duration of time. Nevertheless, these ambient temperatures are conservatively assumed to occur for a significant duration to cause a steady-state temperature distribution in the NUHOMS®-61BT System components.

K.4.5.1 Off-Normal Maximum/Minimum Temperatures during Storage

The thermal performance of the NUHOMS®-61BT DSC within the HSM under the extreme minimum ambient temperature of –40 °F and no insolation is evaluated in Section K.4.4.3.

For the extreme maximum off-normal ambient temperature of 125 °F, a steady state thermal analysis is performed using the 90° symmetric model developed in Section K.4.4.1, the maximum decay heat load of 0.300 kW per assembly (18.3 kW total per DSC), and the DSC temperature distribution shown in Figure K.4-3. A summary of the calculated DSC component temperatures is listed in Table K.4-1.

K.4.5.2 Off-Normal Maximum/Minimum Temperatures during Transfer

The thermal performance of the NUHOMS®-61BT DSC within the OS197 transfer cask under the extreme minimum ambient temperature of –40 °F and no insolation is evaluated in Section 4.4.3. Administrative controls (NUHOMS®-61BT COC Technical Specification 1.2.14) prevent transfer operations of a loaded TC/DSC when ambient temperatures exceed 100 °F. For transfer operations when ambient temperatures exceed 100 °F up to 125 °F, a solar shield is to be used to minimize insolation. Since the thermal performance of the DSC without sunshade at an ambient temperature of 100 °F is limiting, the results presented in Table K.4-1 for the 100 °F ambient case envelope the maximum off-normal 125 °F case.

K.4.5.3 Off-Normal Maximum Internal Pressure during Storage/Transfer

Maximum Internal Pressures

During off-normal conditions, the internal pressure of the NUHOMS®-61BT DSC is calculated assuming the 10% of the fuel rods are failed. For determination of internal pressure within the DSC, it is assumed that 100% of the rod fill gas and 30% of the significant fission gases within the failed fuel rods are available for release into the DSC cavity [4.6]. Using the fuel rod data from Section K.4.4.4., the maximum pressures are calculated.

The average cavity gas temperature during off-normal conditions of storage and transfer are 426°F and 480°F (866 and 940 °R), respectively as shown in Table K.4-1 and Table K.4-2. With rupture of 10% of the fuel rods, the pressures within the DSC are calculated via the ideal gas law:

$$P_{storage} = \frac{nRT}{V} = \frac{(0.498 + (61)(0.10)(9.758E-3))(0.730)(866)}{214.86} = 1.68 \text{ atm } (10.0 \text{ psig})$$

$$P_{transfer} = \frac{nRT}{V} = \frac{(0.498 + (61)(0.10)(9.758E-3))(0.730)(940)}{214.86} = 1.78 \text{ atm } (11.5 \text{ psig})$$

K.4.5.4 Maximum Thermal Stresses

The maximum thermal stresses during off-normal conditions of storage and transfer are calculated in Section K.3.

K.4.5.5 Evaluation of Cask Performance for Off-Normal Conditions

The temperatures in the NUMHOS® HSM and transfer cask are bounded by the existing analysis in the CSAR because of higher heat load for the NUHOMS®-24P or NUHOMS®-52B DSC designs. The NUHOMS®-61BT DSC shell and basket are evaluated for calculated temperatures and pressures in Section K.3. The maximum fuel cladding temperatures are well below the allowable fuel temperature limit of 1058°F (570°C). The pressures remain below 20.0 psig during off-normal conditions of storage and transfer. The pressures and temperatures associated with off-normal conditions in the NUHOMS®-61BT DSC design meet all applicable thermal requirements.

K.4.6 Thermal Evaluation for Accident Conditions

Since the NUHOMS®-61BT HSMs are located outdoors, there is a remote possibility that the ventilation air inlet and outlet openings could become blocked by debris from such unlikely events as floods and tornadoes. The NUHOMS®-61BT System design features such as the perimeter security fence and redundant protected location of the air inlet and outlet openings reduces the probability of occurrence of such an accident. Nevertheless, for this conservative generic analysis, such an accident is postulated to occur and is analyzed.

It is determined in Section 3.3.6 of the SAR [4.8], that the HSM and DSC contain no flammable material and the concrete and steel used for their fabrication can withstand any credible fire accident condition. Fire parameters are dependent on the amount and type of fuel within the transporter and the fire accident condition shall be addressed within site-specific applications. Licensees are required to verify that loadings resulting from potential fires and explosions are acceptable in accordance with 10CFR72.212(b)(2).

K.4.6.1 Blocked Vent Accident Evaluation

For the postulated blocked vent accident condition, the HSM ventilation inlet and outlet openings are assumed to be completely blocked for a 40 hour period concurrent with the extreme off-normal ambient condition of 125 °F with insolation.

For conservatism, a steady state thermal analysis is performed using the 180° symmetric model developed in Section K.4.4.1, the maximum decay heat load of 0.300 kW per assembly (18.3 kW total per DSC), and the DSC temperature distribution shown in Figure K.4-4.

The calculated temperature distribution within the hottest cross-section is shown in Figure K.4-7. A summary of the calculated NUHOMS®-61BT DSC component temperatures is listed in Table K.4-1.

K.4.6.2 Maximum Internal Pressures

The average cavity gas temperature during the blocked vent accident condition is 651 °F (1111 °R). With rupture of one hundred percent of the fuel rods, the pressures within the DSC are calculated via the ideal gas law:

$$P_{accident} = \frac{nRT}{V} = \frac{(0.498 + (61)(1.00)(9.758E-3))(0.730)(1111)}{214.86} = 4.13 \text{ atm } (46.0 \text{ psig})$$

K.4.6.3 Maximum Thermal Stresses

The maximum thermal stresses during accident conditions are calculated in Section K.3.

K.4.6.4 Evaluation of Performance During Accident Conditions

The temperatures in the NUHOMS® HSM are bounded by the existing analyses in the CSAR because of higher heat loads for the NUHOMS®-24P or NUHOMS®-52B DSC designs.

The NUHOMS®-61BT DSC shell and basket are evaluated for calculated pressures and temperatures in Section K.3.

The maximum fuel cladding temperature of 809 °F is below the short-term limit (Section K.4.1) of 1058°F (570°C). The accident pressure in the NUHOMS®-61BT DSC of 46.0 psig remains below the accident design criteria of 65.0 psig. It is concluded that the NUHOMS®-61BT System maintains confinement during the postulated accident condition.

K.4.7 Thermal Evaluation for Loading/Unloading Conditions

All fuel transfer operations occur when the NUHOMS®-61BT DSC/transfer cask is in the spent fuel pool. The fuel is always submerged in free-flowing pool water permitting heat dissipation. After fuel loading is complete, the Cask/DSC is removed from the pool, drained, dried, backfilled with helium and sealed.

The loading condition evaluated for the NUHOMS®-61BT DSC is the heatup of the DSC before its cavity can be backfilled with helium. This typically occurs during the performance of the vacuum drying operation of the DSC cavity. A transient thermal analysis is performed to predict the heatup time history for the NUHOMS®-61BT DSC components assuming air is in the DSC cavity.

K.4.7.1 Vacuum Drying Analysis

Heatup of the DSC prior to being backfilled with helium typically occurs as DSC operations are being performed to drain and dry the DSC. The vacuum drying of the DSC generally does not reduce the pressure sufficiently to reduce the thermal conductivity of the air in the DSC cavity. Analyses are performed to determine both steady state temperatures and the transient heat-up during the vacuum drying condition. For both analyses, all gaseous heat conduction within the NUHOMS®-61BT DSC is through air instead of helium. Radiation heat transfer within the basket is neglected.

K.4.7.1.1 Steady State Vacuum Drying Evaluation

A steady state thermal analysis is performed using the 90° symmetric model developed in Section K.4.4.1, the maximum decay heat load of 0.300 kW per assembly (18.3 kW total per DSC), and a maximum DSC temperature of 369 °F. The resulting fuel cladding temperature is 846 °F, well below the loading/unloading short term cladding temperature limit of 1058 °F.

An additional steady state analysis is performed with a total decay heat load of 17.6 kW per DSC. At this heat load, the basket material temperatures do not exceed 800 °F.

K.4.7.1.2 Transient Vacuum Drying Evaluation

A 16 inch cross-section of the finite element model developed in Section K.4.4.1 is used for the transient vacuum drying evaluation. All temperatures within the DSC and basket are initially assumed to be at 100 °F. The decay heat load for the model corresponds to the 18.3 kW total heat load of the DSC. The DSC temperatures after 96 hours of the vacuum drying condition are listed in Table K.4-4. The results show that at the end of 96 hours, the basket material temperatures do not exceed 800 °F.

K.4.7.1.3 Reflooding Evaluation

For unloading operations, the DSC will be filled with the spent fuel pool water through the siphon port. During this filling operation, the DSC vent port is maintained open with effluents routed to the plant's off-gas monitoring system. The NUHOMS®-61BT DSC operating procedures recommend that the DSC cavity atmosphere be sampled first before introducing any reflood water in the DSC cavity.

When the pool water is added to a DSC cavity containing hot fuel and basket components, some of the water will flash to steam causing internal cavity pressure to rise. This steam pressure is released through the vent port. The procedures also specify that the flow rate of the reflood water be controlled such that the internal pressure in the DSC cavity does not exceed 20 psig. This is assured by monitoring the maximum internal pressure in the DSC cavity during the reflood event. The reflood for the DSC is considered as a service level D event and the design pressure of the DSC is 65 psig. Therefore, there is sufficient margin in the DSC internal pressure during the reflooding event to assure that the DSC will not be over pressurized.

The maximum fuel cladding temperature during reflooding event will be significantly less than the vacuum drying condition due to the presence of water/steam in the DSC cavity. The analysis presented in Section K.4.7.1.1 shows that the maximum cladding temperature during steady state vacuum drying operation is 846°F. Therefore, the maximum cladding temperature during the reflooding operation will be less than 846°F. This is still considerably below the short term cladding temperature limit of 1058°F. Therefore, no cladding damage is expected due to the reflood event. This is also substantiated by the operating experience gained with the loading and unloading of transportation packages like IF-300 [4.10] which show that fuel cladding integrity is maintained during these operations and fuel handling and retrieval is not impacted.

K.4.8 References

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4.3 *American Society for Mechanical Engineers (ASME) Boiler and Pressure Vessel Code*, Section II, Part D, 1998 Edition Including 1999 Addenda.

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4.5 ANSYS, Inc., ANSYS Engineering Analysis System User's Manual for ANSYS Revision 5.6, Houston, PA.

4.6 *Standard Review Plan for Dry Cask Storage Systems*, NUREG-1536, Nuclear Regulatory Commission

4.7 Transnuclear, Inc., *TN-68 Dry Storage Cask Final Safety Analysis Report*, Revision 0, Hawthorne, NY, 2000

4.8 Transnuclear West, *Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Revision 5A*, Fremont, CA.

4.9 Johnson et. al., *Technical Basis for Storage of Zircaloy-Clad Spent Fuel in Inert Gases,* PNL-4835, Pacific Northwest Laboratory, 1983.

4.10 Consolidated Safety Analysis Report for IF-300 Shipping Cask, C of C 9001.

Table K.4-1
NUHOMS®-61BT DSC Component Temperatures During Storage

Component	Normal Conditions			Off-Normal Conditions		Accident Conditions	
	Maximum Temperature (°F)	Minimum Temperature* (°F)	Allowable Range (°F)	125 °F Ambient (°F)	Allowable Range (°F)	Blocked Vent Condition (°F)	Allowable Range (°F)
DSC Wall	318	-40	**	345	**	662	**
Basket Rails	423	-40	**	446	**	722	**
Fuel Compartments/	545	-40	**	566	**	787	**
Fuel Cladding	569	-40	649 max.	590	1058 max	809	1,058 max.
Average Cavity Gas	403	-40	N/A	426	N/A	651	N/A

* Assuming no credit for decay heat and a daily average ambient temperature of -40°F. The –40°F off-normal temperature is used to bound the 0°F normal temperature.

** The components perform their intended safety function within the operating range.

Table K.4-2
NUHOMS®-61BT DSC Component Temperatures During Transfer

Component	Normal Conditions		
	Maximum Temperature (°F)	Minimum Temperature* (°F)	Allowable Range (°F)
DSC Wall	378	-40	**
Basket Rails	493	-40	**
Fuel Compartments/ Poison Plates	615	-40	**
Fuel Cladding	638	-40	1058 max.
Average Cavity Gas	480	-40	N/A

* Assuming no credit for decay heat and a daily average ambient temperature of -40°F. The –40°F off-normal temperature is used to bound the 0°F normal temperature.

** The components perform their intended safety function within the operating range.

Table K.4-3
NUHOMS®-61BT DSC Component Temperatures During Storage and Transfer
(-40 °F Ambient, w/o insolation)

Component	Maximum Temperature (°F)	
	Storage Conditions	Transfer Conditions
DSC Wall	170	308
Basket Rails	295	430
Fuel Compartments/ Poison Plates	425	556
Fuel Cladding	454	580
Average Cavity Gas	273	416

Table K.4-4
Temperature Distribution within the NUHOMS®-61BT DSC
(After 96 Hours of Vacuum Drying Condition)

Component	Maximum Temperature (°F)	Allowable Range (°F)
DSC Wall	370	**
Basket Rails	604	**
Fuel Compartments/ Poison Plates	800	**
Fuel Cladding	827	1,058 max.
Average Cavity Gas	N/A	N/A

** The components perform their intended safety function within the operating range.

Table K.4-5
NUHOMS® 61BT DSC Normal, Off-Normal and Accident Pressures

Case	Maximum Calculated Pressure (psig)		Design Pressure (psig)
	Storage Condition	Transfer Condition	
Normal	7.0	9.0	10.0
Off-Normal	10.0	11.5	20.0
Accident	46.0 (Blocked Vent)	--	65.0

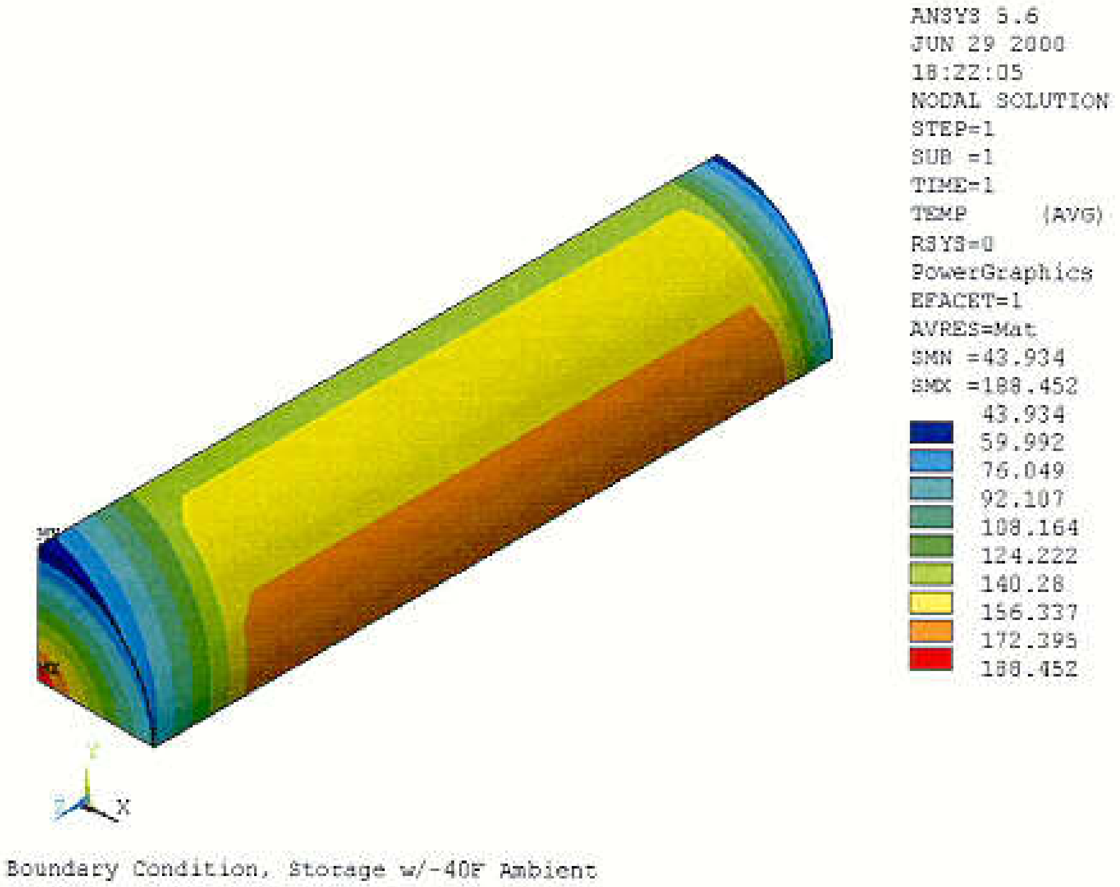

Figure K.4-1
Applied DSC Temperature Distribution
(-40 F Ambient , w/o insolation)

C66

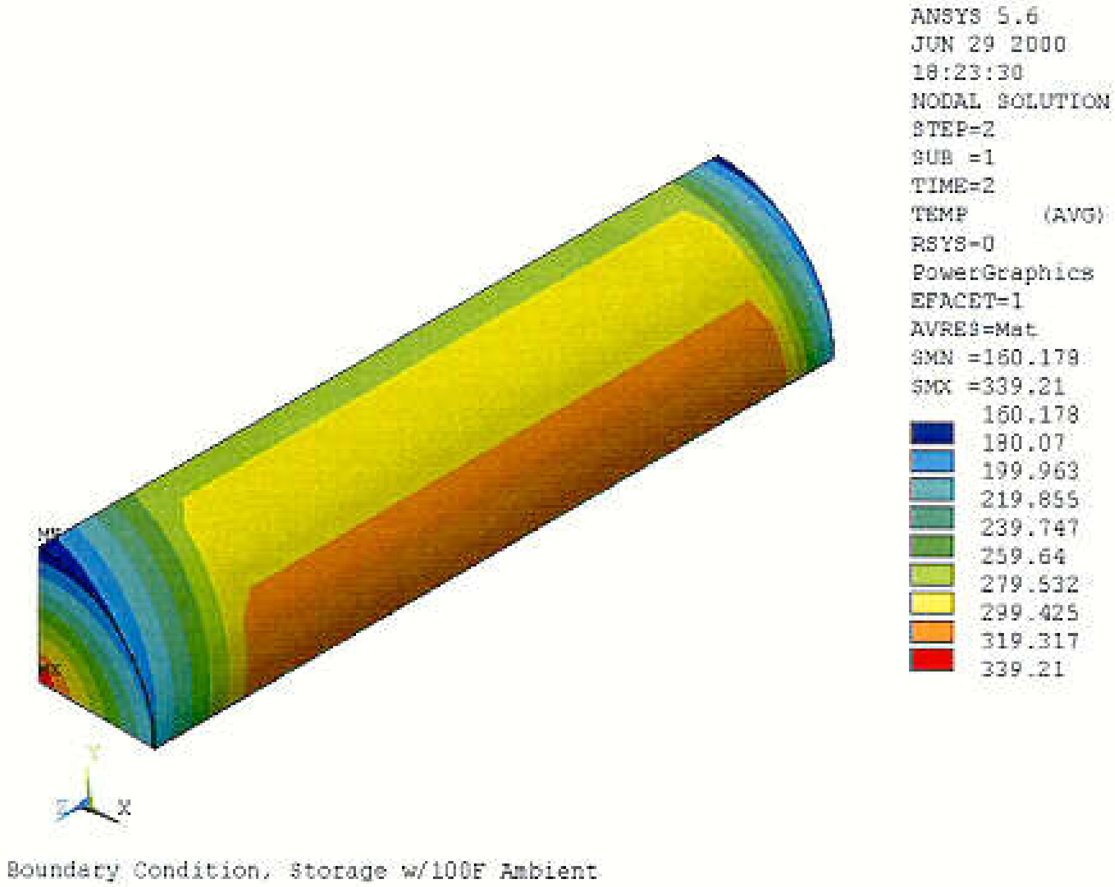

Figure K.4-2
Applied DSC Temperature Distribution
(100 °F ambient w/ insolation)

C67

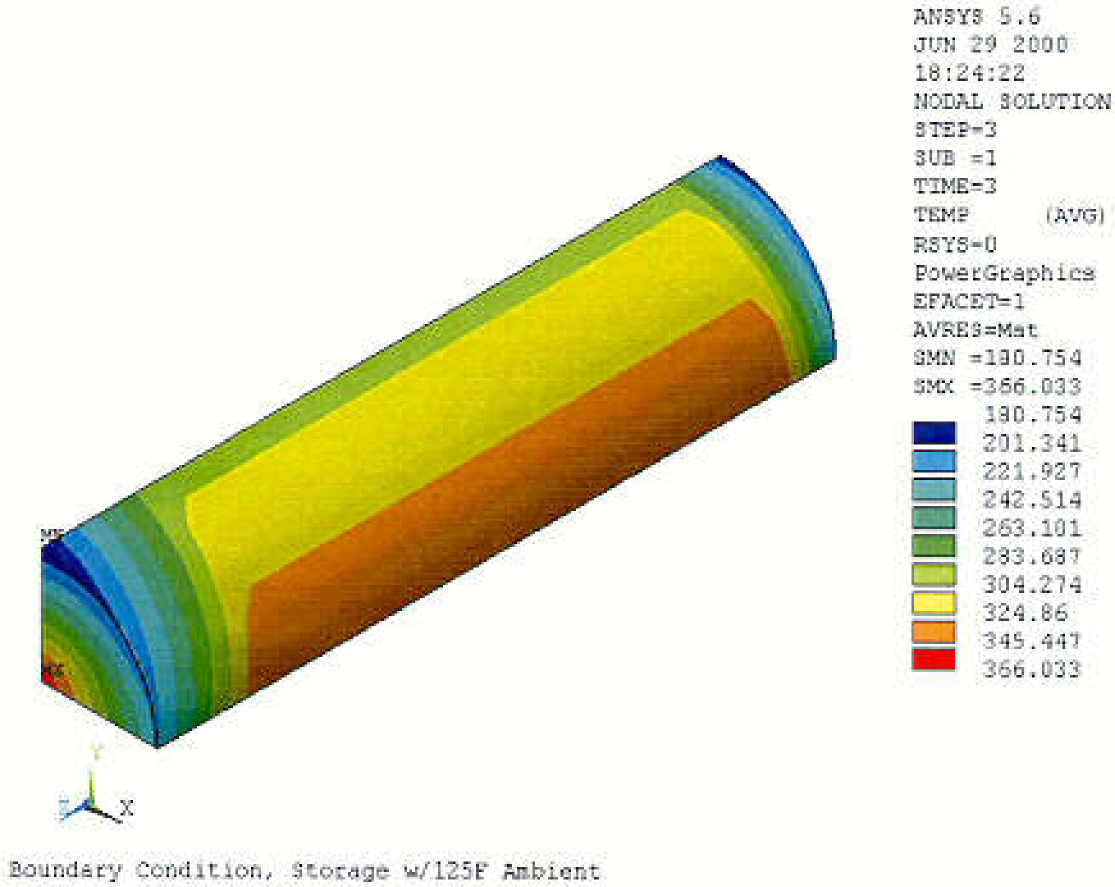

Figure K.4-3
Applied DSC Temperature Distribution
(125 °F ambient w/ insolation)

C68

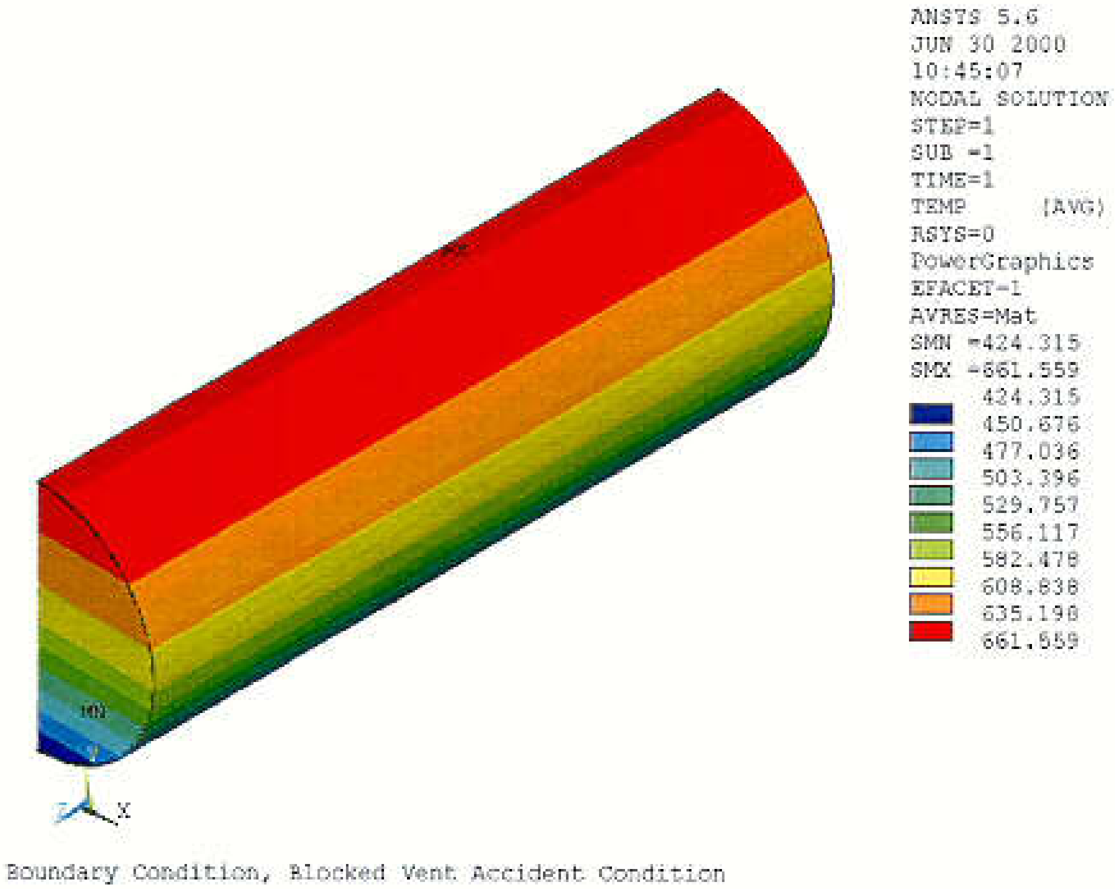

Figure K.4-4
Applied DSC Temperature Distribution
(125°F Ambient Blocked Vent Accident Condition)

C69

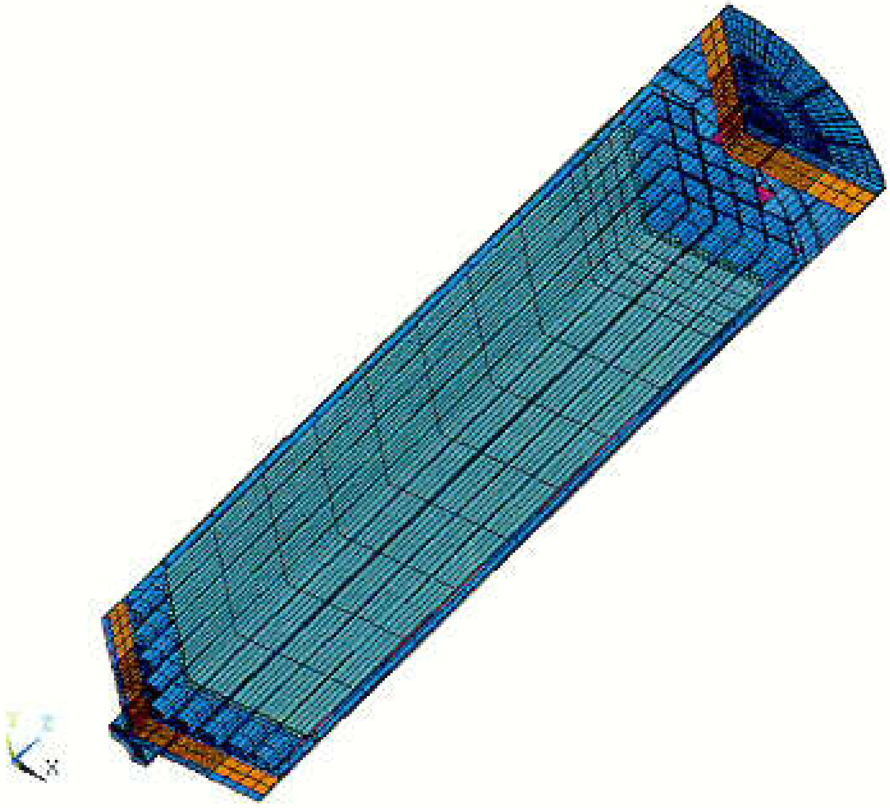

Figure K.4-5
90° Symmetry Finite Element Model of NUHOMS®-61BT DSC

C 70

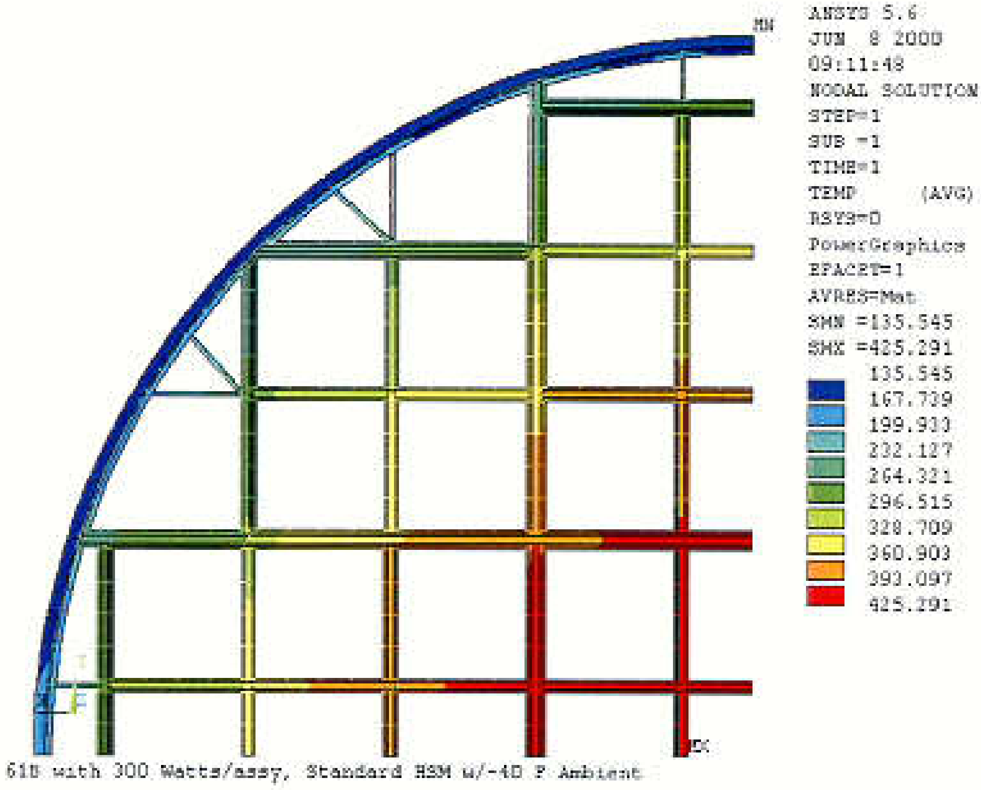

Figure K.4-6
Storage Temperature Distribution Within NUHOMS®-61BT Basket With a -40 °F Ambient
(Hottest Cross-Section)

C71

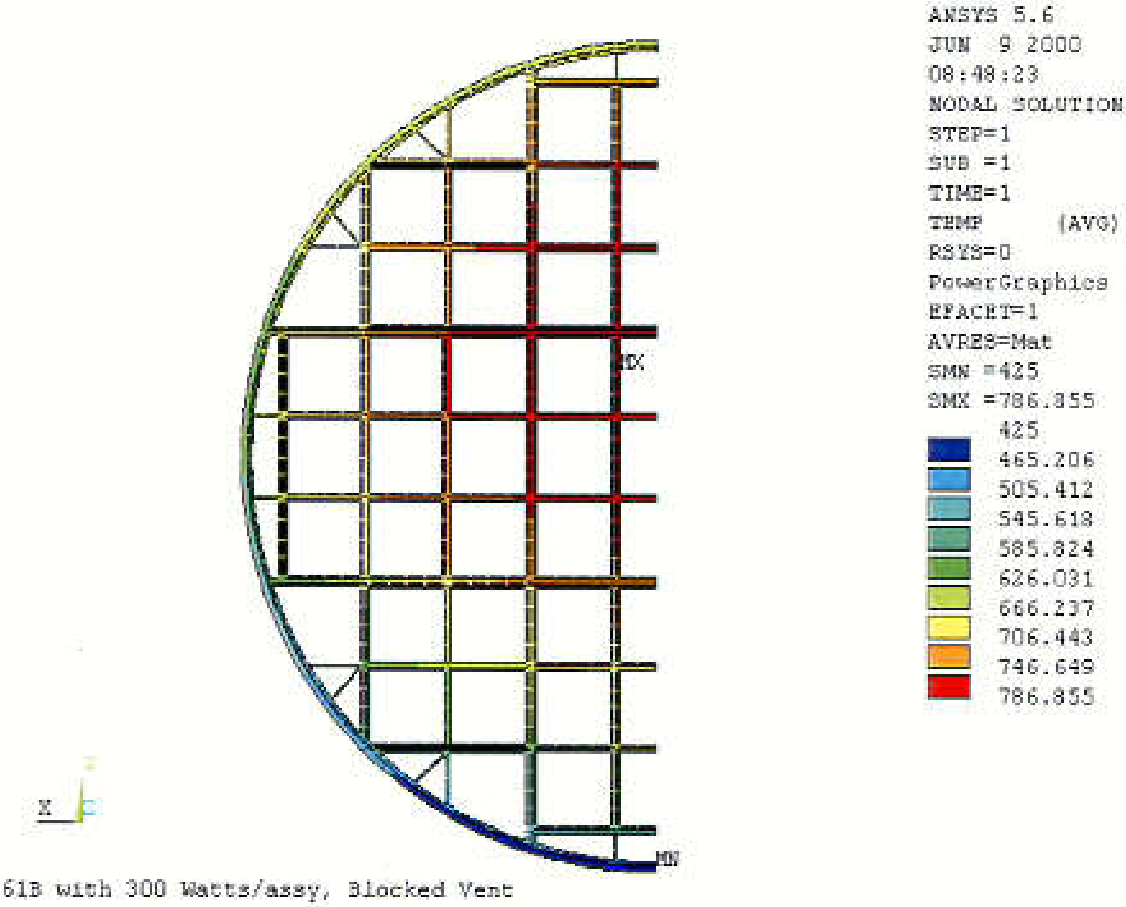

Figure K.4-7
Maximum Temperature Distribution Within NUHOMS®-61BT Basket During 125°F Ambient, Blocked Vent Accident Condition (Hottest Cross-Section)

C.72

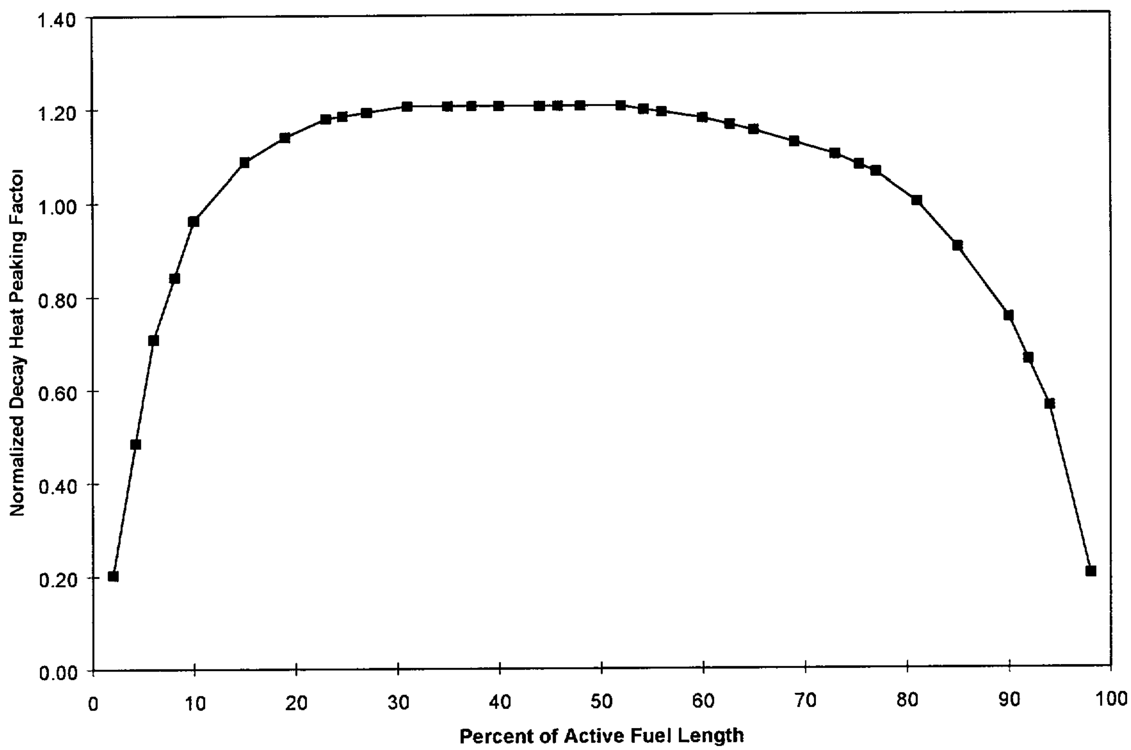

Figure K.4-8
Axial Heat Flux Profile for BWR Fuel