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NUH-003
Revision *11*
NUH003.0103

UPDATED FINAL SAFETY ANALYSIS REPORT FOR THE STANDARDIZED NUHOMS® HORIZONTAL MODULAR STORAGE SYSTEM FOR IRRADIATED NUCLEAR FUEL

PUBLIC

By
Transnuclear, Inc.
Columbia, MD

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J.12-1	6	October 2001
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K.9-1	8	June 2004	Page ii	7	November 2003
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K.9-3	*11*	*February 2010*	Page iv	7	November 2003

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L.14-1	6	October 2001
Page i	8	June 2004
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Page iv	8	June 2004
Page v	8	June 2004
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Page vii	*11*	*February 2010*
Page viii	*11*	*February 2010*
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Page xv	8	June 2004
Page xvi	8	June 2004
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DWG (sh. 1 of 4) NUH-32PT-1004NP-SAR	3	1/30/06

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DWG (sh. 4 of *9*) NUH-03-6400-SAR	*1*	*Not shown*
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DWG (sh. 4 of 5) NUH-61BTH-1000-SAR	*11*	*Not shown*

DWG (sh. 5 of 5) NUH-61BTH-1000-SAR	*11*	*Not shown*
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DWG (sh. 4 of 4) NUH-61BTH-2000-SAR	*11*	*Not shown*
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T.3.5-31 (accounts for T.3.5-31 through T.3.5-33)	11	February 2010
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DWG (sh. 1 of 3) NUH32PTH1-1001-SAR	11	Not shown
DWG (sh. 2 of 3) NUH32PTH1-1001-SAR	11	Not shown
DWG (sh. 3 of 3) NUH32PTH1-1001-SAR	11	Not shown
DWG (sh. 1 of 2) NUH32PTH1-1002-SAR	11	Not shown
DWG (sh. 2 of 2) NUH32PTH1-1002-SAR	11	Not shown
DWG (sh. 1 of 5) NUH32PTH1-1003-SAR	11	Not shown
DWG (sh. 2 of 5) NUH32PTH1-1003-SAR	11	Not shown
DWG (sh. 3 of 5) NUH32PTH1-1003-SAR	11	Not shown
DWG (sh. 4 of 5) NUH32PTH1-1003-SAR	11	Not shown
DWG (sh. 5 of 5) NUH32PTH1-1003-SAR	11	Not shown
DWG (sh. 1 of 4) NUH32PTH1-1004-SAR	11	Not shown
DWG (sh. 2 of 4) NUH32PTH1-1004-SAR	11	Not shown
DWG (sh. 3 of 4) NUH32PTH1-1004-SAR	11	Not shown
DWG (sh. 4 of 4) NUH32PTH1-1004-SAR	11	Not shown
DWG (sh. 1 of 5) NUH32PTH1-1005-SAR	11	Not shown
DWG (sh. 2 of 5) NUH32PTH1-1005-SAR	11	Not shown
DWG (sh. 3 of 5) NUH32PTH1-1005-SAR	11	Not shown
DWG (sh. 4 of 5) NUH32PTH1-1005-SAR	11	Not shown
DWG (sh. 5 of 5) NUH32PTH1-1005-SAR	11	Not shown
DWG (sh. 1 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 2 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 3 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 4 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 5 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 6 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 7 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 8 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 9 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 10 of 10) NUH-03-7003-SAR	11	Not shown
DWG (sh. 1 of 3) NUH-08-8001-SAR	11	Not shown
DWG (sh. 2 of 3) NUH-08-8001-SAR	11	Not shown
DWG (sh. 3 of 3) NUH-08-8001-SAR	11	Not shown
DWG (sh. 1 of 3) NUH-08-8002-SAR	11	Not shown
DWG (sh. 2 of 3) NUH-08-8002-SAR	11	Not shown
DWG (sh. 3 of 3) NUH-08-8002-SAR	11	Not shown
DWG (sh. 1 of 3) NUH-08-8003-SAR	11	Not shown
DWG (sh. 2 of 3) NUH-08-8003-SAR	11	Not shown
DWG (sh. 3 of 3) NUH-08-8003-SAR	11	Not shown
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U.2-9	*11*	*February 2010*
U.2-10	*11*	*February 2010*
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U.2-15	*11*	*February 2010*
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U.2-44	*11*	*February 2010*
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U.3.4-13	*11*	*February 2010*
U.3.4-14	*11*	*February 2010*
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U.3.4-16	*11*	*February 2010*
U.3.5-1	*11*	*February 2010*
U.3.5-2	*11*	*February 2010*
U.3.5-3	*11*	*February 2010*
U.3.5-4 (accounts for U.3.5-4 through U.3.5-8)	*11*	*February 2010*
U.3.5-9	*11*	*February 2010*
U.3.5-10	*11*	*February 2010*
U.3.5-11	*11*	*February 2010*
U.3.5-12	*11*	*February 2010*
U.3.5-13	*11*	*February 2010*
U.3.5-14 (accounts for U.3.5-14 and U.3.5-15)	*11*	*February 2010*
U.3.5-16	*11*	*February 2010*
U.3.5-17	*11*	*February 2010*
U.3.5-18	*11*	*February 2010*
U.3.5-19	*11*	*February 2010*
U.3.5-20	*11*	*February 2010*
U.3.5-21	*11*	*February 2010*
U.3.5-22	*11*	*February 2010*
U.3.5-23	*11*	*February 2010*
U.3.5-24	*11*	*February 2010*
U.3.5-25	*11*	*February 2010*
U.3.5-26	*11*	*February 2010*
U.3.5-27	*11*	*February 2010*
U.3.5-28	*11*	*February 2010*
U.3.6-1	*11*	*February 2010*
U.3.6-2	*11*	*February 2010*
U.3.6-3	*11*	*February 2010*

U.3.6-4	11	February 2010
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U.3.6-7	11	February 2010
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U.3.6-36 (accounts for U.3.6-36 through U.3.6-46)	11	February 2010
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U.3.6-48	11	February 2010
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U.3.6-61	11	February 2010
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U.3.6-69	11	February 2010
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U.3.6-111	11	February 2010
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U.3.6-113	11	February 2010
U.3.6-114 (accounts for U.3.6-114 through U.3.6-123)	11	February 2010
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U.3.7-3	11	February 2010

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U.3.7-14	11	February 2010
U.3.7-15	11	February 2010
U.3.7-16	11	February 2010
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U.5-89	11	February 2010
U.5-90	11	February 2010
U.5-91	11	February 2010
U.5-92	11	February 2010
U.5-93	11	February 2010
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U.6-168	11	February 2010

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U.11-12	11	February 2010
U.11-13	11	February 2010
U.11-14	11	February 2010
U.11-15	11	February 2010

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U.13-1	*11*	*February 2010*
U.14-1	*11*	*February 2010*
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ii of iv	10	February 2008
iii of iv	10	February 2008
iv of iv	10	February 2008
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V.1-2	10	February 2008
V.1-3	10	February 2008
V.1-4	10	February 2008
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V.2-1	10	February 2008
V.2-2	10	February 2008
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V.4-7	10	February 2008
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V.10-1	10	February 2008
V.11-1	10	February 2008
V.11-2	10	February 2008
V.11-3	*11*	*February 2010*
V.11-4	10	February 2008

V.11-5	10	February 2008
V.12-1	10	February 2008
V.13-1	10	February 2008
V.14-1	10	February 2008
Page i	10	February 2008
Page ii	10	February 2008
Page iii	10	February 2008
Page iv	10	February 2008
Page v	10	February 2008
W.1-1	10	February 2008
W.1-2	10	February 2008
W.1-3	10	February 2008
W.1-4	10	February 2008
W.1-5	10	February 2008
DWG (sh. 1 of 8) NUH-03-8008-SAR	0	Not shown
DWG (sh. 2 of 8) NUH-03-8008-SAR	0	Not shown
DWG (sh. 3 of 8) NUH-03-8008-SAR	0	Not shown
WG (sh. 4 of 8) NUH-03-8008-SAR	0	Not shown
DWG (sh. 5 of 8) NUH-03-8008-SAR	0	Not shown
DWG (sh. 6 of 8) NUH-03-8008-SAR	0	Not shown
DWG (sh. 7 of 8) NUH-03-8008-SAR	0	Not shown
DWG (sh. 8 of 8) NUH-03-8008-SAR	0	Not shown
DWG (sh. 1 of 6) NUH-03-8009-SAR	0	Not shown
DWG (sh. 2 of 6) NUH-03-8009-SAR	0	Not shown
DWG (sh. 3 of 6) NUH-03-8009-SAR	0	Not shown
DWG (sh. 4 of 6) NUH-03-8009-SAR	0	Not shown
DWG (sh. 5 of 6) NUH-03-8009-SAR	0	Not shown
DWG (sh. 6 of 6) NUH-03-8009-SAR	0	Not shown
DWG (sh. 1 of 2) NUH-03-8010-SAR	0	Not shown
DWG (sh. 2 of 2) NUH-03-8010-SAR	0	Not shown
W.1-6	10	February 2008
W.1-7	10	February 2008
W.1-8	10	February 2008
W.1-9	10	February 2008
W.1-10	10	February 2008
W.1-11	10	February 2008

W.1-12	10	February 2008
W.2-1	10	February 2008
W.2-2	10	February 2008
W.2-3	10	February 2008
W.3-1	10	February 2008
W.3-2	10	February 2008
W.3-3	10	February 2008
W.3-4	10	February 2008
W.3-5	10	February 2008
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W.3-7	10	February 2008
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W.3-10	10	February 2008
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W.8-14	10	February 2008
W.9-1	10	February 2008
W.10-1	10	February 2008
W.11-1	10	February 2008
W.11-2	10	February 2008
W.11-3	10	February 2008
W.12-1	10	February 2008
W.13-1	10	February 2008
W.14-1	10	February 2008

This appendix contains the following items:

E.1 Drawings for NUHOMS® Dry Shielded Canisters(1)

- E.1.1 Standardized NUHOMS®-24P DSC Drawings
- E.1.2 Standardized NUHOMS®-52B DSC Drawings
- E.1.3 Standardized NUHOMS®-24P Long Cavity DSC Drawings

E.2 Drawings for NUHOMS® Horizontal Storage Module(2)*(4)* (HSM Model 80 and Model 102 only)

E.3 Drawings for NUHOMS® On-Site Transfer Cask(3) *(OS197/OS197H)*

(1) The drawings for the NUHOMS®-61BT, 24PT2 and 32PT DSCs are contained in Appendices K, L and M, respectively. The drawings for the NUHOMS®-24PHB DSCs are contained in Appendices E and N. The drawings for the NUHOMS®-24PTH *DSC* are contained in Appendix P. *The drawings for the 61BTH and 32PTH1 DSCs are contained in Appendix T and U, respectively.*

(2) The drawings for the NUHOMS® HSM Model 152 and Model 202 are contained in Section R.1.5 of Appendix R and V.1.5 of Appendix V, respectively.

(3) The drawings for the NUHOMS® OS197L transfer cask are contained in Section W.1.5 of Appendix W. *The drawings for the OS197FC/OS197HFC transfer cask are contained in Appendix P. The drawings for the OS197FC-B/OS197HFC-B are contained in Appendix P and Appendix T. The drawings for the OS200/OS200FC are contained in Appendix U.*

(4) The drawings for the HSM-H are contained in Appendix P and Appendix T. The drawings for the HSM-HS are contained in Appendix U.

APPENDIX E.1

DRAWINGS FOR NUHOMS® DRY SHIELDED CANISTERS

Appendix E.1.1

This Appendix contains the following drawings of the standardized NUHOMS®-24P system:

Drawing Number	Title
NUH-03-1020-SAR	General License NUHOMS® DSC for PWR Fuel Basket Assembly
NUH-03-1021-SAR	General License NUHOMS® DSC for PWR Fuel Shell Assembly
NUH-03-1022-SAR	General License NUHOMS® DSC for PWR Fuel Basket-Shell Assembly
NUH-03-1023-SAR	General License NUHOMS® DSC for PWR Fuel Main Assembly

SECURITY RELATED INFORMATION

NUH-03-1023-SAR 1 OF 3

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

This drawing may not be disclosed to others in whole or in part, or used for other than the transmitted purpose without written permission of Transnuclear, Inc.

TRANSNUCLEAR
AN AREVA COMPANY

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® DSC
FOR PWR FUEL
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-1023-SAR	NONE	1 OF 3	7

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

Appendix E.1.2

This Appendix contains the following drawings of the standardized NUHOMS®-52B system:

Drawing Number	Title
NUH-03-1029-SAR	General License NUHOMS® DSC for Channeled BWR Fuel Shell Assembly
NUH-03-1030-SAR	General License NUHOMS® DSC for Channeled BWR Fuel Basket-Shell Assembly
NUH-03-1031-SAR	General License NUHOMS® DSC for Channeled BWR Fuel Main Assembly
NUH-03-1032-SAR	General License NUHOMS® DSC for Channeled BWR Fuel, BWR Fuel Basket Assembly

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

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Transnuclear, Inc.

TRANSNUCLEAR
AN AREVA COMPANY

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® DSC FOR CHANNELLED BWR FUEL
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-1031-SAR	NONE	1 OF 3	7

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

Appendix E.1.3

This Appendix contains the following drawings of the standardized NUHOMS®-24P Long Cavity system:

Drawing Number	Title
NUH-03-1050-SAR	General License NUHOMS® 24P Long Cavity DSC Basket Assembly
NUH-03-1051-SAR	General License NUHOMS® 24P Long Cavity DSC Shell Assembly
NUH-03-1052-SAR	General License NUHOMS® 24P Long Cavity DSC Basket-Shell Assembly
NUH-03-1053-SAR	General License NUHOMS® 24P Long Cavity DSC Main Assembly

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS®
24P LONG CAVITY DSC
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-1053-SAR	NONE	1 OF 3	4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

APPENDIX E.2

DRAWINGS FOR NUHOMS® HORIZONTAL STORAGE MODULE

Appendix E.2

This Appendix contains the following drawings for the standardized NUHOMS® horizontal storage module:

Drawing Number	Title
NUH-03-6008-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module ISFSI General Arrangement
NUH-03-6009-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module Main Assembly
NUH-03-6010-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module Base Unit Assembly
NUH-03-6014-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module Base Unit
NUH-03-6015-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module Roof Slab Assembly
NUH-03-6016-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module DSC Support Structure
NUH-03-6017-01-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module, Module Accessories
NUH-03-6018-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module Shield Wall Plans and Details
NUH-03-6024-SAR	Standardized NUHOMS® ISFSI Horizontal Storage Module, Module Erection Hardware

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

TRANSNUCLEAR
AN AREVA COMPANY

SAFETY ANALYSIS REPORT
STANDARDIZED NUHOMS® ISFSI
HORIZOTAL STORAGE MODULE
ISFSI GENERAL ARRANGEMENT

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-6008-SAR	NONE	1 OF 3	9

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

NUH-03-6009-SAR 1 OF 2

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
STANDARDIZED NUHOMS® ISFSI
HORIZOTAL STORAGE MODULE
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-6009-SAR	NONE	1 OF 2	8

NUH-03-6009-SAR 2 OF 2

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
STANDARDIZED NUHOMS® ISFSI
HORIZOTAL STORAGE MODULE
DSC SUPPORT STRUCTURE

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-6016-SAR	NONE	1 OF 2	10

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
STANDARDIZED NUHOMS® ISFSI
HORIZOTAL STORAGE MODULE
MODULE ERECTION HARDWARE

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-6024-SAR	NONE	1 OF 2	5

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

APPENDIX E.3

DRAWINGS FOR NUHOMS® ON-SITE TRANSFER CASK

Appendix E.3

This Appendix contains the following drawings for the standardized NUHOMS® On-site Transfer Cask:

Drawing Number	Title
NUH-03-8000-SAR	General License NUHOMS® ISFSI On-Site Transfer Cask Overview
NUH-03-8001-SAR	General License NUHOMS® ISFSI On-Site Transfer Cask Structural Shell Assembly
NUH-03-8002-SAR	General License NUHOMS® ISFSI On-Site Transfer Cask Inner and Outer Shell Assembly
NUH-03-8003-SAR	General License NUHOMS® ISFSI On-Site Transfer Cask Main Assembly

NUH-03-8000-SAR 1 OF 1

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
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SAFETY ANALYSIS REPORT

GENERAL LICENSE NUHOMS® ISFSI ONSITE TRANSFER CASK OVERVIEW

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-8000-SAR	NONE	1 OF 1	5

DRAWING NO. NUH-61B-1060-SAR SHEET 1 OF 2

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
NUHOMS® 61BT TRANSPORTABLE CANISTER FOR BWR FUEL GENERAL ARRANGEMENT

DRAWING NO.	SCALE	SHEET	REVISION
NUH-61B-1060-SAR	NONE	1 OF 2	5

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
NUHOMS® 61BT TRANSPORTABLE CANISTER FOR BWR FUEL SHELL ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-61B-1061-SAR	NONE	1 OF 2	4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
NUHOMS® 61BT TRANSPORTABLE CANISTER FOR BWR FUEL CANISTER DETAILS

DRAWING NO.	SCALE	SHEET	REVISION
NUH-61B-1062-SAR	NONE	1 OF 2	5

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
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SAFETY ANALYSIS REPORT
NUHOMS® 61BT TRANSPORTABLE CANISTER FOR BWR FUEL
BASKET DETAILS

DRAWING NO.	SCALE	SHEET	REVISION
NUH-61B-1064-SAR	NONE	1 OF 2	4

8 7 6 5 4 3 2

NUH-61B-1064-SAR 2 OF 2

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PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
NUH-61B-1064-SAR	2 OF 2	4

8 7 6 5 4 3 2 1

NUH-61B-1065-SAR 1 OF 1

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
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SAFETY ANALYSIS REPORT
NUHOMS® 61BT TRANSPORTABLE CANISTER FOR BWR FUEL PARTS LIST

DRAWING NO.	SCALE	SHEET	REVISION
NUH-61B-1065-SAR	NONE	1 OF 1	4

NUH-03-1070-SAR 1 OF 4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS® 24PT2S-DSC
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-1070-SAR	NONE	1 OF 4	2

8 7 6 5 4 3 2 1

NUH-03-1070-SAR 2 OF 4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
NUH-03-1070-SAR	2 OF 4	2

8 7 6 5 4 3 2 1

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
NUHOMS® 32PT TRANSPORTABLE STORAGE CANISTER FOR PWR FUEL MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-32PT-1001-SAR	NONE	1 OF 3	5

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

NUH32PTH1-1001-SAR 3 OF 3

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION	TRANSNUCLEAR AN AREVA COMPANY
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.	
INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4	SAFETY ANALYSIS REPORT NUHOMS® 32PT TRANSPORTABLE STORAGE CANISTER FOR PWR FUEL SHELL ASSEMBLY
U.S. Patent No. 4,780,269 Transnuclear, Inc.	DRAWING NO. NUH-32PT-1002-SAR; SCALE NONE; SHEET 1 OF 2; REVISION 4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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SAFETY ANALYSIS REPORT

GENERAL LICENSE NUHOMS®
24PHBS AND 24PHL DSC

DRAWING NO.	SCALE	SHEET	REVISION
NUH-HBU-1000-SAR	NONE	1 OF 6	2

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

8 7 6 5 4 3 2 1

NUH-HBU-1000-SAR 4 OF 6

H G F E D C B A

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
NUH-HBU-1000-SAR	4 OF 6	2

8 7 6 5 4 3 2 1

NUH-HBU-1000-SAR 5 OF 6

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

NUH-HBU-1000-SAR 6 OF 6

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
NUHOMS® 24PTH TRANSPORTABLE STORAGE DSC FOR PWR FUEL MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH24PTH-1001-SAR	NONE	1 OF 4	3

NUH24PTH-1001-SAR 1 OF 4

8 7 6 5 4 3 2 1

NUH24PTH-1001-SAR 2 OF 4

H G F E D C B A

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
NUHOMS® 24PTH TRANSPORTABLE STORAGE DSC FOR PWR FUEL BASKET ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH24PTH-1003-SAR	NONE	1 OF 7	2

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

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SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

NUH-03-7001-SAR 1 OF 11

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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SAFETY ANALYSIS REPORT
STANDARDIZED NUHOMS® ISFSI
HSM-H
MAIN ESSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-7001-SAR	NONE	1 OF 11	4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

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NUH-03-7001-SAR 9 OF 11

H G F E D C B A

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
NUH-03-7001-SAR	9 OF 11	4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

NUH-03-6400-SAR 1 OF 9

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

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SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS® HSM MODEL 152
MAIN ESSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-6400-SAR	NONE	1 OF 9	1

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

8 7 6 5 4 3 2

NUH-03-6400-SAR 6 OF 9

PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
NUH-03-6400-SAR	6 OF 9	1

8 7 6 5 4 3 2 1

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

8 7 6 5 4 3 2

NUH-03-6400-SAR 9 OF 9

H G F E D C B A

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
NUH-03-6400-SAR	9 OF 9	1

8 7 6 5 4 3 2 1

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

TRANSNUCLEAR
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SAFETY ANALYSIS REPORT
NUHOMS® 61BTH DSC TYPE 1
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-61BTH-1000-SAR	NONE	1 OF 5	0

NUH-61BTH-1000-SAR 2 OF 5

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

NUH-61BTH-1000-SAR 4 OF 5

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION	TRANSNUCLEAR AN AREVA COMPANY
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.	SAFETY ANALYSIS REPORT
INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4	NUHOMS® 61BTH DSC TYPE 2 MAIN ASSEMBLY
U.S. Patent No. 4,780,269 Transnuclear, Inc.	DRAWING NO. NUH61BTH-2000-SAR; SCALE NONE; SHEET 1 OF 4; REVISION 0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

8 7 6 5 4 3 2 1

NUH-61BTH-2000-SAR 4 OF 4

H G F E D C B A

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
NUH-61BTH-2000-SAR	4 OF 4	0

NUH61BTH-2001-SAR 1 OF 2

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

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SAFETY ANALYSIS REPORT

NUHOMS® 61BTH DSC TYPE 2 SHELL ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH61BTH-2001-SAR	NONE	1 OF 2	0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269
Transnuclear, Inc.

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SAFETY ANALYSIS REPORT

NUHOMS® 61BTH DSC TYPE 2
BASKET ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH61BTH-2002-SAR	NONE	1 OF 6	0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

NUH-61BTH-2002-SAR 3 OF 6

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

NUH-61BTH-2002-SAR 6 OF 6

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

SECURITY RELATED INFORMATION

NUH61BTH-2003-SAR 1 OF 1

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

TRANSNUCLEAR AN AREVA COMPANY

SAFETY ANALYSIS REPORT

NUHOMS® 61BTH DSC TYPE 2 TRANSITION RAILS

DRAWING NO.	SCALE	SHEET	REVISION
NUH61BTH-2003-SAR	NONE	1 OF 1	0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

TRANSNUCLEAR
AN AREVA COMPANY

SAFETY ANALYSIS REPORT

NUHOMS® 61BTH DSC TYPE 2 DAMAGED FUEL END CAPS

DRAWING NO.	SCALE	SHEET	REVISION
NUH61BTH-2004-SAR	NONE	1 OF 1	0

NUH61BTH-2004-SAR 1 OF 1

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

ALL DIMENSIONS ARE NOMINAL UNLESS A SPECIFIC TOLERANCE IS INDICATED WITH THE DRAWING DIMENSION

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE SPECIFIED. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5M.

INTERPRET WELD SYMBOLS PER ANSI / AWS 2.4

U.S. Patent No. 4,780,269 Transnuclear, Inc.

TRANSNUCLEAR
AN AREVA COMPANY

SAFETY ANALYSIS REPORT
GENERAL LICENSE NUHOMS® ISFSI
OS197FC-B ONSITE TRANSFER CASK
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET	REVISION
NUH-03-8007-SAR	NONE	1 OF 1	0

T.3 Structural Evaluation

T.3.1 Structural Design

T.3.1.1 Discussion

This section describes the structural evaluation of the NUHOMS®-61BTH system. The NUHOMS®-61BTH system consists of the NUHOMS® HSM (Models 80, 102, 152, 202) and HSM-H, the OS197/OS197H/OS197FC-B transfer casks, and the 61BTH Type 1 and Type 2 DSCs. No changes have been made to the HSM to accommodate the 61BTH DSCs. Minor changes have been made to the HSM-H and the OS197FC to accommodate the 61BTH DSC. These changes consist of a reduced door thickness to provide adequate canister length in the HSM-H, a modified vented top lid in the OS197FC and use of spacer plates at the bottom of the OS197FC TC to allow air circulation when needed. The OS197FC with those modifications is referred as the OS197FC-B. Where the new components have an effect on the structural evaluations presented in UFSAR Chapters 3 and 8, the changes are included in this section. Sections that do not effect the evaluations presented in Chapters 3 or 8 or the appropriate appendix of the UFSAR are identified as "No Change." In addition, a complete evaluation of the 61BTH Type 1 and Type 2 DSCs are provided in this section.

The 61BTH Type 1 DSC is the same as the 61BT DSC documented in Appendix K with the following additional features/options:

Two alternate bottom closure details have been added. Alternate 2 reduces the Bottom Shield Plug by 1" and increases the Inner Bottom Cover Plate by 1". The Inner Bottom Cover Plate and a portion of the DSC cylindrical shell is made of a single forging. Alternate 3 replaces the Outer Bottom Cover Plate, Bottom Shield Plug, Inner Bottom Cover Plate and a portion of the DSC cylindrical shell with a single solid forging.

As an option to the holddown ring, an alternate Top Grid design that is integral with the basket has been added to provide additional flexibility in fuel assembly loading operations.

The 61BTH Type 1 DSC is shown on drawing NUH61BTH-1000-SAR in Section T.1.5. Drawing NUH61BTH-1000-SAR also documents the additional features/options implemented in the 61BTH Type 1 DSC with respect to the 61BT DSC and refers to the 61BT drawings in Appendix K.

The 61BTH Type 2 DSC shell assembly is shown on drawings NUH61BTH-2000-SAR and NUH61BTH-2001-SAR. The shell assembly for the 61BTH Type 2 DSC is the same as the 61BTH Type 1 DSC with the following exceptions:

The Inner Top Cover Plate thickness has been increased from ¾" to 1¼".

The Outer Top Cover Plate thickness has been increased from 1¼" to 1½".

The Top Shield Plug thickness has been reduced from 7" to 6¼" to accommodate the increased thickness of the top cover plates.

The bottom edge of the Top Shield Plug has a cutout to accommodate the Support Ring.

Only one lifting lug design configuration is provided (i.e., no alternate designs).

The NUHOMS®-61BTH Type 1 and Type 2 baskets are welded assemblies 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 61BTH Type 1 basket assembly is shown on drawings NUH61BTH-1000-SAR, in Section T.1.5. The 61BTH Type 1 basket is based on the 61BT basket documented in Appendix K. The 61BTH Type 2 basket assembly is shown on drawings NUH61BTH-2002-SAR, NUH61BTH-2003-SAR and NUH61BTH-2004 in Section T.1.5.

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° *(Type 1 DSC) and at 0° and 180° (Type 2 DSC)* and therefore its orientation with respect to the DSC always remains fixed. Under normal transfer conditions, the DSC rests on two 3" wide transfer support rails, attached to the inside of the transfer cask at 161.5° and 198.5°.

The Type 1 basket assembly is the same as the 61BT basket described in Appendix K and consists of:

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 transition rails, fabricated from 0.19/0.25 in. thick, SA-240, Type 304 stainless steel.

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

The Type 2 basket assembly is the same as the 61BT basket described in Appendix K with the exception that it incorporates aluminum material in the transition rails to improve its thermal efficiency. The Type 2 basket consists of:

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 R45 transition rail assemblies fabricated from 0.19/0.25 in. thick, SA-240, Type 304 stainless steel plate and 0.63 in. thick B209 Type 1100 aluminum plate.

Four (4) Type R90 transition rail assemblies fabricated from 0.25 in. thick, SA-240, Type 304 stainless steel plate and solid Type 6061 aluminum pieces.

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.

The transition 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 or top grid is located between the top of the basket assembly and inside surface of the DSC top shield plug assembly. The holddown ring or top grid prevents the basket assembly from sliding freely in the axial direction.

End caps are installed at the bottom and top of basket cells which contain damaged fuel. The top end cap is attached to the fuel compartment through a compartment extension, which ensures that the fuel assembly is fully enclosed within the fuel compartment. The holddown ring or top grid for damaged fuel provides clearance for the top end cap and extension hardware at the locations of damaged fuel basket cells. The damaged fuel Type 1 basket details are shown on Drawing NUH61B-1066-SAR in Section K.1.5 when the holddown ring is used and in Drawing NUH61BTH-1000-SAR when the optional top grid is used. The damaged fuel Type 2 basket details are shown on Drawing NUH61BTH-2004-SAR in Section T.1.5.

T.3.1.2 Design Criteria

Design criteria for this section are provided in Section T.2.5.

T.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, and the associated welds. Figure T.3.1-1 provides a graphic representation of the 61BTH DSC confinement boundary.

The welds made during fabrication of the 61BTH DSC that affect the confinement boundary of the DSC include the weld applied to the inner bottom cover plate and the circumferential and longitudinal seam welds applied to the shell. These welds are inspected (radiographic or ultrasonic inspection, and liquid penetrant inspection) in accordance with the requirements of Subsection NB of the ASME Code. The vent and siphon block weld is also made during fabrication and is liquid penetrant inspected in accordance with Subsection NB of the ASME Code.

The welds applied to the vent and siphon port covers and the inner top cover plate during closure operations define the confinement boundary at the top end of the 61BTH DSC. These welds are applied using a multiple-layer technique with multi-level PT in accordance with Subsection NB of the ASME Code. Alternatives to ASME code are provided in Table T.3.1-2.

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 T.2.2 for additional design criteria.

T.3.1.2.2 DSC Basket

The basket is designed to meet the heat transfer, nuclear criticality, and structural requirements. The basket structure provides sufficient rigidity to maintain a subcritical configuration under the applied loads. The 304 stainless steel members in the NUHOMS®-61BTH basket are the primary structural components. The neutron poison plates are the primary heat conductors, and provide the necessary criticality control. In the Type 2 basket additional heat conduction is provided by the aluminum plates and solid aluminum pieces in the R45 and R90 transition rails, respectively.

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 T.2.2 for additional design criteria. The basket stress limits are provided in Table T.3.1-1.

The basket holddown ring (or the alternate top grid) is located between the top of the basket assembly and the inside surface of the DSC top shield plug. The holddown ring (or alternate top grid) 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 and the alternate top grid are designed, fabricated and inspected in accordance with the ASME Code Subsections NF and NG, respectively, to the maximum practical extent.

T.3.1.2.3 ASME Code Alternatives for the 61BTH DSC

The primary confinement boundary of the NUHOMS®-61BTH DSC 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 plates. Even though the Code is not strictly applicable to the DSC, it is TN's intent to follow Section III, Subsection NB of the Code as closely as possible for design and construction of the confinement vessel. The DSC may, however, be fabricated by other than N-stamp holders and materials may be supplied by other than ASME Certificate Holders. Thus the requirements of NCA are not imposed. TN's quality assurance requirements, which are based on 10CFR72 Subpart G, are imposed in lieu of the requirements of NCA-3800. The SAR is prepared in place of the ASME design and stress reports. Surveillances are performed by TN and utility personnel rather than by an Authorized Nuclear Inspector (ANI).

The basket is designed, fabricated and inspected in accordance with the ASME Code Subsection NG, to the maximum practical extent.

The poison and aluminum plates are not considered for structural integrity. Therefore, these materials are not required to be code materials. The *TN* quality assurance requirements are imposed in lieu of NCA-3800. The basket is not code stamped. Therefore the requirements of NCA are not imposed. Fabrication and inspection surveillances are performed by TN and utility personnel rather than by an ANI.

A complete list of the ASME Code alternatives and justification for the confinement boundary of the NUHOMS®-61BTH DSC and basket is provided in Table T.3.1-2 and Table T.3.1-3, respectively.

Table T.3.1-1
Primary Stress Intensity Limits

(304 SS at 750°F)

Stress Category	Allowable Stresses			
	Normal Conditions (Level A)	**Seismic Conditions (Level C)**	**Accident Conditions (Level D)**	
	Elastic Analysis (ksi)	**Elastic Analysis (ksi)**	**Elastic/Plastic Analysis (ksi)**	**Elastic Analysis (ksi)**
Primary Membrane Stress Intensity (P_m)	15.6	18.7	44.31	37.4
Local Membrane Stress Intensity (P_L)	23.4	28.1	56.97	56.2
Primary Membrane + Bending Stress Intensity ($P_m + P_b$)	23.4	28.1	56.97	56.2
Primary Membrane + Secondary Stress Intensity Range ($P_m + P_b + Q$)	46.8	N/A	N/A	N/A
Shear	8.19	8.19	26.6	26.6
Bearing Stress (S_b)	25.8	25.8	N/A	N/A

Table T.3.1-2
ASME Code Alternatives for the NUHOMS®-61BTH DSC Confinement Boundary

Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
NCA	All	Not compliant with NCA.
NB-1100	Requirements for Code Stamping of Components	The NUHOMS®-61BTH DSC shell, the inner top cover, the inner bottom cover, and siphon/vent port cover are designed & fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.
NB-1132	Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component.	Bottom shield plug, outer bottom cover plate grapple ring, and grapple ring support are outside code jurisdiction; these components together are much larger than required to provide stiffening for the inner bottom cover plate; the weld that retains the outer bottom cover plate and with it the bottom shield plug is subject to root and final PT examination.
NB-2130	Material must be supplied by ASME approved material suppliers.	Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.
NB-4121	Material Certification by Certificate Holder	
NB-4243 and NB-5230	Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. These welds shall be examined by UT or RT and either PT or MT.	The shell to the outer top cover weld, the shell to the inner top cover/weld, the siphon/vent cover welds and the vent and siphon block welds to the shell are all partial penetration welds. As an alternative to the NDE requirements of NB-5230 for Category C welds, all of these closure welds will be multi-layer welds and receive a root and final PT examination, except for the shell to the outer top cover weld. The shell to the outer top cover weld will be a multi-layer weld and receive multi-level PT examination in accordance with the guidance provided in ISG-15 for NDE. The multi-level PT Examination provides reasonable assurance that flaws of interest will be identified. The PT examination is done by qualified personnel, in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000. All of these welds will be designed to meet the guidance provided in ISG-15 for stress reduction factor.

Table T.3.1-2
ASME Code Alternatives for the NUHOMS®-61BTH DSC Confinement Boundary
(Concluded)

Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
NB-6100 and 6200	All completed pressure retaining systems shall be pressure tested	The 61BTH is not a complete or "installed" pressure vessel until the top closure is welded following placement of Fuel Assemblies with the DSC. Due to the inaccessibility of the shell and lower end closure welds following fuel loading and top closure welding, as an alternative, the pressure testing of the DSC is performed in two parts. The DSC shell (including all longitudinal and circumferential welds) is pressure tested and examined at the fabrication facility. The shell to the inner top cover closure weld are pressure tested and examined for leakage in accordance with NB-6300 in the field. The siphon/vent cover welds are not pressure tested; these welds and the shell to the inner top cover closure weld are helium leak tested after the pressure test. Per NB-6324 the examination for leakage shall be done at a pressure equal to the greater of the design pressure or three-fourths of the test pressure. As an alternative, if the examination for leakage of these field welds, following the pressure test, is performed using helium leak detection techniques, the examination pressure may be reduced to ≥ 1.5 psig. This is acceptable given the significantly greater sensitivity of the helium leak detection method.
NB-7000	Overpressure Protection	No overpressure protection is provided for the NUHOMS® -61BTH DSC . The function of the NUHOMS®-61BTH DSC is to contain radioactive materials under normal, off-normal and hypothetical accident conditions postulated to occur during transportation and storage. The NUHOMS®-61BTH DSC is designed to withstand the maximum possible internal pressure considering 100% fuel rod failure at maximum accident temperature.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000	The NUHOMS®-61BTH DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the NUHOMS®-61BTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72 and TN's approved QA program.

Table T.3.1-3
ASME Code Alternatives for the NUHOMS®-61BTH DSC Basket

Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
NG/NF-1100	Requirements for Code Stamping of Components	The NUHOMS®-61BTH DSC baskets are designed and fabricated in accordance with the ASME Code, Section III, Subsection NG to the maximum extent practical as described in the SAR, but Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME N or NPT stamp or be ASME Certified.
NG-2000	Use of ASME Material	The poison material and aluminum plates are not used for structural analysis, but to provide criticality control and heat transfer. They are not ASME Code Class 1 material. Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits.
NG/NF-2130	Materials must be supplied by ASME approved material suppliers	Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG/NF-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program. The poison material and aluminum plates are not certified to ASME requirements.
NG/NF-4121	Material Certification by Certificate Holder	
NCA	All	Not compliant with NCA as no code stamp is used. TN Quality Assurance requirements, which are based on 10CFR72 Subpart G, are used in lieu of NCA-4000. Fabrication oversight is performed by TN and utility personnel in lieu of an Authorized Nuclear Inspector.
NG-3352	Table NG 3352-1 lists the permissible welded joints and quality factors.	The fuel compartment tubes may be fabricated from sheet with full penetration seam weldments. Per Table NG-3352-1 a joint efficiency (quality) factor of 0.5 is to be used for full penetration weldments examined in accordance with ASME Section V visual examination (VT). A joint efficiency (quality) factor of 1.0 is utilized for the fuel compartment longitudinal seam welds (if present) with VT examination. This is justified because the compartment seam weld is thin and the weldment is made in one pass; and both surfaces of the weldment (inside and outside) receive 100% VT examination. The 0.5 quality factor, applicable to each surface of the weldment, results is a quality factor of 1.0 since both surfaces are 100% examined. In addition, the fuel compartments have no pressure retaining function and the stainless steel material that comprises the fuel compartment tubes is very ductile.
NG-8000	Requirements for nameplates, stamping & reports per NCA-8000	The NUHOMS® 61BTH DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the NUHOMS® 61BTH DSC. In lieu of Code stamping, QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72 and TN's approved QA program.

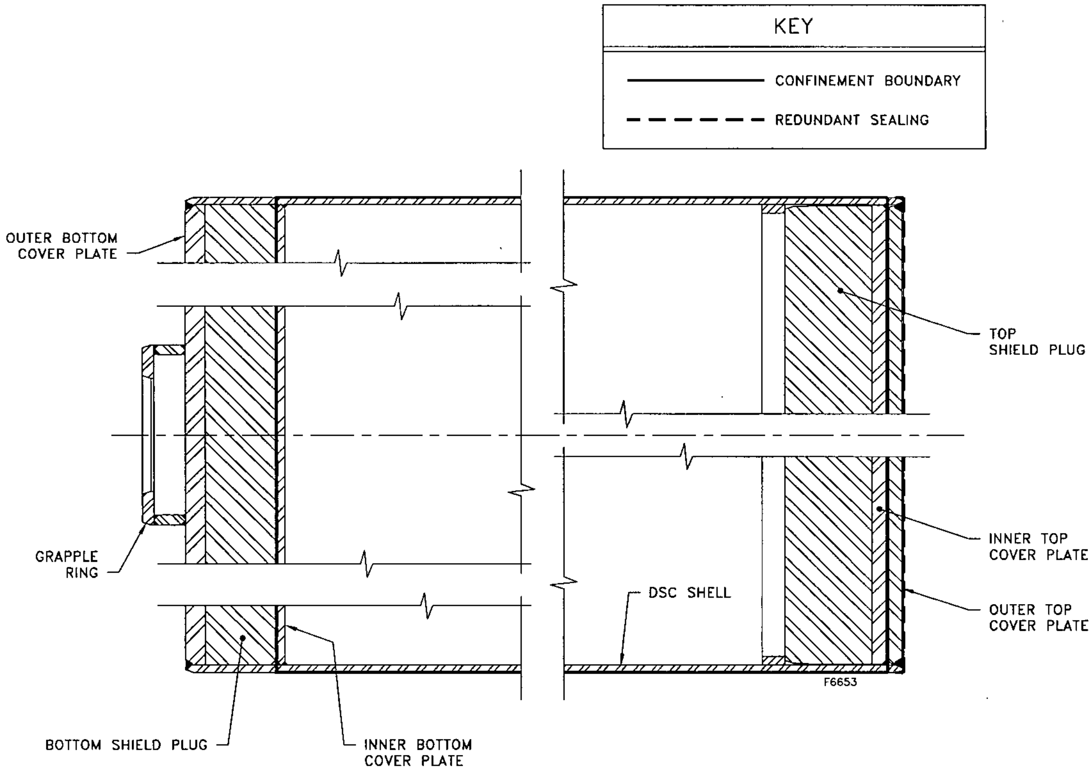


Figure T.3.1-1
61BTH DSC Confinement Boundary

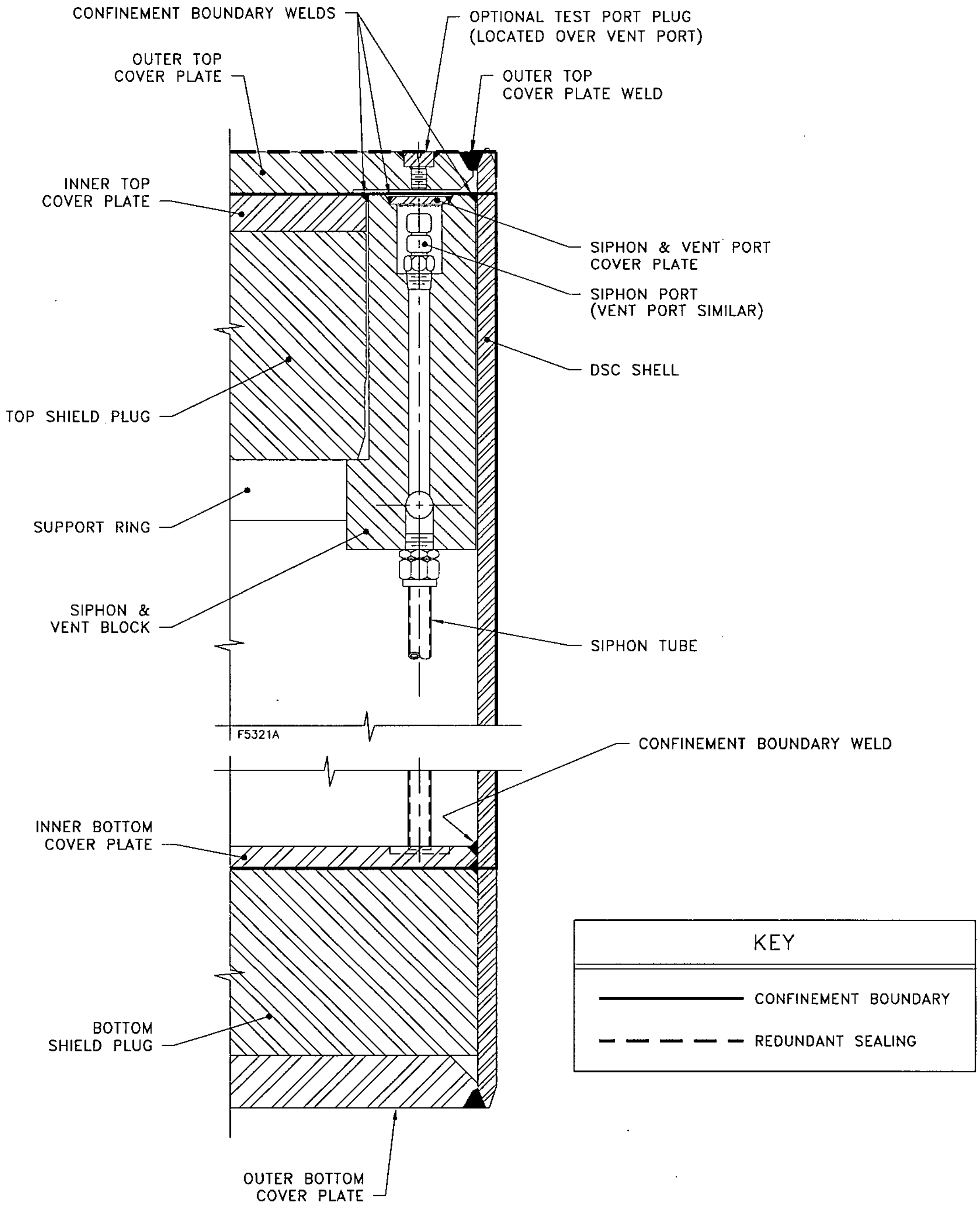


Figure T.3.1-1
61BTH DSC Confinement Boundary
(Concluded)

T.3.2 Weights

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

Table T.3.2-1
Summary of the NUHOMS®-61BTH System Component Weights[4]

Component Description	Calculated Weight (kips)
Type 1 DSC Shell Assembly	13.43
Type 1 DSC Top Shield Plug and Top Cover Plates	8.90
Type 1 DSC Internal Basket Assembly	23.37
Type 1 DSC Total Empty Weight	**45.70**
Type 2 DSC Shell Assembly	13.43
Type 2 DSC Top Cover Plates and Shield Plug	8.90
Type 2 DSC Internal Basket Assembly	27.79
Type 2 DSC Total Empty Weight	**50.12**
61 BWR Spent Fuel Assemblies	≤ 43.0
Total Loaded Type 1 DSC Weight (Dry)	**88.70**
Total Loaded Type 2 DSC Weight (Dry)	**93.12**
Water in Loaded Type 1 DSC	13.91
Water in Loaded Type 2 DSC	12.08
Total Loaded Type 1 DSC Weight (Wet)[1]	**93.71**
Total Loaded Type 2 DSC Weight (Wet)[1]	**96.30**
Transfer Cask Empty Weight (with Neutron Shield/Top Lid)	111.25
Total Type 1 Loaded Transfer Cask Weight (Dry/Wet)	**199.95[2]/204.96[3]**
Total Type 2 Loaded Transfer Cask Weight (Dry/Wet)	**204.37[2]/207.55[3]**
HSM Single Module Weight, Model 80/102 (Empty)	263.0
HSM Single Module Weight, Model 152 (Empty)	318.3
HSM-H/202 Single Module Weight (Empty)	306.1
HSM Single Module Weight, Model 80/102 (Loaded)	351.7[2]/356.1[3]
HSM Single Module Weight, Model 152 (Loaded)	407.0[2]/411.4[3]
HSM-H/202 Single Module Weight (Loaded)	394.8[2]/399.2[2]

Notes:
(1) Without top shield plug and top cover plates
(2) Loaded with bounding weight of Type 1 61BTH DSC
(3) Loaded with Type 2 61BTH DSC
(4) Weights are based on nominal dimensions.

T.3.3 Mechanical Properties of Materials

T.3.3.1 Material Properties

The mechanical properties of structural materials used in the 61BTH DSC and basket are in accordance with ASME Code Section II, Part D [3.2]. Values used for the thermal coefficient of expansion for Zircaloy are taken from reference [3.3].

T.3.3.2 Materials Durability

The materials used in the fabrication of the NUHOMS®-61BTH system are shown in Table T.3.6-3. The materials that make up the 61BTH system 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 aluminum material used in the basket meets ASME Code standards and is primarily relied upon for its thermal conductivity properties . The poison materials selected for criticality control have proven operational experience for use in similar applications. Additionally, the materials that make up the basket internals of the NUHOMS®-61BTH DSC are exposed to an inert helium gas environment for the majority of their design life. The specifications controlling the mix of the concrete, specified minimum concrete strength requirements, and fabrication controls ensure durability of the HSM/HSM-H concrete for this application. The materials used in the NUHOMS®-61BTH system will maintain the required properties for the design life of the system.

T.3.4 General Standards for Casks

T.3.4.1 Chemical and Galvanic Reactions

The materials of the 61BTH 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 61BTH DSC is exposed to the following environments:

During loading and unloading, the DSC is placed in pool water, inside the 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/HSM-H. The HSM/HSM-H 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®-61BTH DSC materials are shown in the Parts List on Drawings NUH61B-1065-SAR and NUH61B-1066-SAR, provided in Section K.1.5 and Drawings NUH61BTH-1000-SAR, NUH61BTH-2000-SAR, NUH61BTH-2001-SAR, NUH61BTH-2002-SAR, NUH61BTH-2003-SAR, and NUH61BTH-2004-SAR in Section T.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. As an option, the top shield plug material may be SA-240 Type 304 stainless steel (no coating required).

The neutron poison materials in the basket consist of enriched boron aluminum or boron carbide/aluminum, metal matrix composite or Boral™ 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 Type 1 basket rails are constructed from SA-240 Type 304 stainless steel plate. The Type 2 basket rails are constructed from SA-240 Type 304 stainless steel plate, wrapped with B209 Type 1100 aluminum plates (R45 rails) and solid Type 6061 aluminum pieces (R90 rails). The basket holddown ring/top grid top structure is constructed from SA-240, Type 304 stainless steel.

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

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 T.3.4-1 shows a potential versus 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.

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.

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 *which has* a matrix of full-density aluminum with a fine dispersion of boron carbide particles. 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.

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'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

Cleaning agents used for final cleaning on the NUHOMS®-61BTH DSC should be selected for compatibility with the spent fuel pool water chemistry and the DSC materials. 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 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 61BTH 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®-61BTH 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

In addition to the neutron poison plates, aluminum plates or solid pieces are used in the basket transition rails for thermal conduction. The total surface area of the aluminum for the Type 1 basket, considering the possibility that the aluminum plates could be made of multiple pieces, is conservatively estimated to be 4,472 ft^2. To ensure that the hydrogen concentration is below the NRC-accepted limit of 2.4% (see Section 5.1.1.3 of the main body of this SAR), a minimum of 929 gallons of water should be drained from the Type 1 DSC. This results in a maximum submerged surface area of aluminum of not more than 2,326 ft^2. This surface area, combined with the test data at 150°F above result in a hydrogen generation rate of

$$(1.6x10^{-4}\ ft^3/ft^2hr)(2,326\ ft^2)\ =0.372\ ft^3/hr$$

in the 61BTH Type 1 DSC. During welding of the inner top cover plate, the DSC is partially filled with water. The minimum free volume of the Type 1 DSC is 124.1 ft^3 (based on 929 gallons of drained 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 (0.372 ft^3 H_2/hr)*(8 hr) / (124.1 ft^3) = 2.40%.

Similarly, for the Type 2 basket, the total surface area of the aluminum is 4,844 ft^2. A minimum of 900 gallons of water should be drained from the Type 2 DSC which results in a maximum submerged surface area of aluminum of not more than 2,255 ft^2. This results in a hydrogen generation rate of

$$(1.6x10^{-4}\ ft^3/ft^2hr)(2,255\ ft^2) = 0.361\ ft^3/hr$$

in the 61BTH Type 2 DSC. The minimum free volume of the Type 2 DSC is 120.3 cubic feet (based on 900 gallons of drained water). Therefore, the hydrogen concentration is

$$(0.361\ ft^3\ H_2/hr)(8\ hr) / (120.3\ ft^3) = 2.4\%$$

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 0.2, 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 0.74, 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.

T.3.4.2 Positive Closure

Positive closure is provided by the OS197/OS197H/OS197FC-B transfer cask. No change.

T.3.4.3 Lifting Devices

As described in Section 8.1.19(B), the evaluations for the OS197 and OS197H TC trunnions are based on critical lift weights (with water in the DSC) of 208,500 lbs and 250,000 lbs, respectively. These lifted weights capacities are not changed for the OS197FC-B since the only design features that are different between the OS197/OS197H and the OS197FC-B are the introduction of vent passages around the circumference of the top lid (similar to those in the OS197FC) and the addition of wedge shaped plates at the TC bottom to distribute the incoming air to the TC/DSC annular space. The maximum critical lift weight with a NUHOMS®-61BTH DSC is approximately 204,400 lbs (dry) or 207,600 lbs (wet). Therefore, an OS197FC-B TC that is based on the OS197H design is acceptable with any NUHOMS®-61BTH DSC. An OS197FC-B TC that is based on the OS197 design is limited to a total critical lift weight of 208,500 lbs.

T.3.4.4 Heat and Cold

T.3.4.4.1 Summary of Pressures and Temperatures

Temperatures and pressures for the 61BTH DSC and basket are calculated in Section T.4. Section T.4.4 provides the thermal evaluation of the HSM and HSM-H loaded with a 61BTH DSC. Section T.4.5 provides the thermal evaluation of the OS197/OS197H/OS197FC-B transfer casks loaded with a 61BTH DSC. Section T.4.6 provides the thermal evaluation of the 61BTH DSC. Section T.4.7 provides the thermal evaluation for fuel loading/unloading conditions, including during vacuum drying operations. Tables T.4-12, T.4-17, and T.4-21 summarize the maximum fuel cladding temperatures for normal, off-normal and accident conditions. Tables T.4-13, T.4-14, T.4-18, T.4-19, T.4-22, and T.4-23 summarize the 61BTH DSC maximum component temperatures for normal, off-normal and accident conditions. Tables T.4-16, T.4-20, and T.4-24 summarize the maximum DSC cavity pressures for normal, off-normal and accident conditions. Tables T.4-25, T.4-26, and T.4-27 summarize fuel cladding and basket component temperatures for vacuum drying conditions.

T.3.4.4.2 Temperatures and Thermal Expansion

The thermal analyses of the basket for the handling/transfer conditions are described in Section T.4. The thermal analyses are performed to determine the basket/DSC temperatures and thermal expansion for -40°F ambient, 0°F ambient, 117°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.

In order to prevent thermal stress, adequate clearance is provided between the following components:

Fuel Assemblies and DSC Cavity (Section T.3.4.4.2.1)

Basket Rails and DSC Shell (Section T.3.4.4.2.2)

Basket and DSC Shell Ends (Section T.3.4.4.2.3)

Neutron Absorber Plates and Basket Plate Inserts (Section T.3.4.4.2.4)

Basket Rail Aluminum and DSC Shell Ends (Section T.3.4.4.2.5)

To verify that adequate clearance exists, the thermal expansion of different components are calculated and tabulated in the following sections.

T.3.4.4.2.1 Fuel Assemblies and DSC Cavity

This calculation verifies that there is adequate space for thermal expansion of the irradiated fuel Zircaloy clad assemblies within the DSC cavity for all operating conditions. The longest fuel of 176.50" and minimum DSC cavity length of 178.41" are considered in this analysis. The minimum cold gap available for differential thermal expansion and irradiation growth of the fuel assembly is 178.41-176.50=1.91". It is conservatively assumed that the maximum irradiation growth of 61BTH BWR fuel assemblies is 1.75".

The clearance for the irradiated fuel assembly within DSC cavity is calculated as the difference of the hot lengths of the 61BTH DSC cavity and the fuel assembly.

The total hot irradiated fuel assembly length (including irradiation growth) is determined as:

$$L_{FA\ hot\ irradiated} = L_{FA\ hot} + \Delta L_{FA\ \ irradiation}$$

where:

$L_{FA\ hot\ irradiated}$	Hot irradiated length of the fuel assembly, *in*
$L_{FA\ hot}$	Length of the fuel assembly after thermal expansion, *in*
$\Delta L_{FA\ hot\ irradiated}$	Irradiation growth of the fuel assembly, *in*

The thermal expansion of the DSC cavity is given by the following formula:

$$L_{DSC\ hot} = L_{DSC\ cold}\,[1 + \alpha_{steel} \cdot (T_{ave} - T_{ref})]$$

where:

$L_{DSC\ hot}$	DSC cavity hot length, *in*
$L_{DSC\ cold}$	DSC cavity cold length at reference temperature, *in* (178.41 in)
α_{steel}	Steel coefficient of thermal expansion, $°F^{-1}$ (8.99E-6/°F at 223°F)
T_{ref}	Reference temperature, *°F* (70°F)
T_{ave}	DSC shell volumetric average temperature, *°F*

The fuel assembly hot length $L_{FA\ hot}$ calculation considers thermal expansion of the active fuel and the top and bottom end fittings, with their corresponding average material temperatures:

$$L_{FA\ hot} = L_{active\ fuel\ cold}(1+\alpha_{Zr}(T_{ave\ active\ fuel}-T_{ref})) + L_{fitting\ cold}(1+\alpha_{Steel}(T_{ave\ fitting}-T_{ref}))$$

where:

$L_{active\ fuel\ cold}$	Cold length of the active fuel, *in* (144.0 in)
α_{Zr}	Zircaloy coefficient of thermal expansion, $°F^{-1}$ (2.96E-6/°F at 600°F)
$T_{ave\ active\ fuel}$	Active fuel volumetric average temperature, *°F*
$L_{fitting\ cold}$	Cold length of the fuel fitting, *in* (32.502 in)
$T_{ave\ fitting}$	Fuel fitting volumetric average temperature, *°F*

The average temperature for the active fuel, and the fuel end fittings are calculated for the hottest fuel assembly. The fuel end fittings also include the inactive fuel regions.

The average temperatures of the DSC shell, active fuel region, and fuel end fittings are calculated as:

$$T_{ave\ component} = \frac{\sum (T_i \cdot V_i)_{element}}{\sum V_{i\ element}},$$

where T_i, V_i are temperature and volume of component elements.

The thermal expansion calculations are performed using bounding cladding average temperature of 600°F and average DSC shell temperature of 223°F. Using the above formulae, the length of the fuel assembly after the thermal expansion is calculated as 176.833" and the DSC shell hot length is calculated as 178.655". Thus, the gap between the fuel assembly and end assemblies is 178.655-176.833=1.82". This gap is sufficient to accommodate the conservatively assumed irradiation growth of 1.75". It is therefore concluded that the provision of 1.91" minimum gap is sufficient and acceptable.

T.3.4.4.2.2 Radial Gap between Basket and DSC Shell

The radial gap between the basket and the DSC shell is evaluated to verify that there is sufficient initial cold gap for the basket to expand without imposing significant stress on the DSC shell.

The nominal DSC inner diameter is 66.25". The radial cold gap between the basket rails and the 61BTH DSC shell can vary between 0.125" and 0.2".

Average volumetric temperatures for the components that affect the basket and shell thermal expansion are computed. These temperatures, with the corresponding thermal expansion coefficients, are applied to the basket and rail components to calculate the gap in the hot condition.

D_1, Hot Diametric Gap =

$$ID_{SHELL} \cdot (1 + \alpha_{SHELL}(T_{SHELL} - 70)) - L_{BASKET}(1 + \alpha_{BASKET}(T_{BASKET} - 70)) \cdot$$

where ID_{shell} is the inner diameter of the DSC shell, and L_{basket} is the total length of the basket components across the basket section in the radial direction

T is the volumetric average temperature of the component,

α is the expansion coefficient of the component at component temperature

Hot Radial Gap $= D_1 / 2$

Using the above formula, the minimum hot radial gap (clearance) is calculated as 0.035 inch. Thus, there is no interference between the basket and DSC shell.

A condition may exist where the gap between the DSC basket and shell is reduced below the minimum specified in the design drawings due to local distortion of the shell, thereby constituting controlling locations for basket to shell gap. These local conditions involve the potential for a zero basket to shell gap, which could impose loads on the shell due to differential thermal expansion between the basket and shell. This condition has been specifically evaluated in the design basis analytical model and demonstrated to satisfy ASME Code stress allowable values such that the design basis compliance for the DSC confinement boundary is maintained.

T.3.4.4.2.3 Axial Gap between Basket and DSC Shell

The total minimum gap between the basket assembly (which includes the basket and the top grid) and the DSC end assemblies is 0.6" (Type 1 DSC).

The basket average temperature is conservatively based on the volumetric average temperature of the hottest fuel assembly. The shell temperature is calculated by averaging the hottest and the coldest temperatures of the shell. A nominal length of 178.5" is used for the calculation of the axial gap between the basket and the DSC shell. The reduction in the axial gap available for thermal expansion is evaluated as:

Basket / Shell Gap Reduction =

$$178.5 \cdot [(1 + (T_{BASKET} - 70) \cdot \alpha_{BASKET}) - (1 + (T_{SHELL} - 70) \cdot \alpha_{SHELL})]$$

For the controlling case the maximum shell average temperature is 338°F and the basket average temperature is 606°F (Type 2 DSC). The largest computed gap reduction is 0.50". This gap reduction is less than the provided minimum gap of 0.6". Therefore, there is sufficient axial gap to accommodate relative thermal expansion between the basket and the DSC ends.

T.3.4.4.2.4 Axial Gap between Neutron Absorber and Basket Plate Inserts

Basket plate inserts are welded to the fuel compartments at both ends. These inserts become the end restraints for the thermal expansion or movement of the neutron absorber. The total minimum gap between the basket plate inserts and the neutron absorber is 0.75". A nominal neutron absorber plate length of 156" is used for the calculation.

The maximum fuel cladding temperature is 858°F (for the Type 1 DSC accident blocked vents storage condition @ 40 hours). Conservatively a temperature of 900°F is used for both the neutron absorber and the fuel compartment. The aluminum coefficient of expansion is used for the neutron absorber, and the SA-204 Type 304 coefficient of expansion is used for the fuel compartment.

Neutron Absorber / Basket Plate Inserts Axial End Gap Reduction =

$$156 \cdot [(1 + (T_{Fuel\,Compartment} - 70) \cdot \alpha_{Fuel\,Compartment}) - (1 + (T_{Neutron\,Absorber} - 70) \cdot \alpha_{Neutron\,Absorber})]$$

The calculation shows that the gap reduction due to thermal condition is 0.518". Therefore, the provided gap of 0.75" is acceptable.

T.3.4.4.2.5 Axial Gap between Aluminum Rail and End Components (Bottom Assembly and Top Grids)

The length of the R90 (aluminum) rails in the Type 2 DSCs is sized 1.0 inch smaller than the adjacent stainless steel fuel compartments in consideration of their higher thermal expansion. In addition, the basket is sized to have a nominal 1.0 inch gap to accommodate basket thermal expansion.

Applying a conservatively bounding rail temperature of 735°F (blocked vent accident condition at 40 hours), the thermal growth of the aluminum rails is calculated to be on the order of 1.62 inches which is less than the 2.0 inches gap available.

T.3.4.4.3 Thermal Stress Calculations

The thermal stress calculations for the various system components other than the basket and basket rails are provided in Sections T.3.6 and T.3.7 for normal, off-normal and accident conditions. The thermal stress calculations and results for the 61BTH basket are presented below in Subsection A. The thermal stress results for the 61BTH basket rails are presented below in Subsection B.

A. Thermal Stress Analysis of the Basket

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) R45 (or Type 1) rails and four (4) R90 (or 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. The most significant thermal stresses in the basket are due to the radial gradient, which is largest at the cross-section where the maximum temperature occurs. These thermal stresses are calculated using an ANSYS model as described below in Subsection 1. Thermal stresses in the outer box (wrap) due to the basket axial thermal gradient are calculated below in Subsection 2. Thermal stresses in the outer box due to thermal expansion of the inner boxes and the thickness of the poison aluminum plates are calculated below in Subsection 3. Thermal stresses in the outer box due to thermal expansion of the aluminum plate for only the vacuum drying condition are calculated below in Subsection 4. Thermal stresses in the basket and canister due to possible radial interference between the basket and the canister during vacuum drying are calculated below in Subsection 5. The results of the ANSYS analyses and the calculated values are conservatively combined and shown below in Subsection 6. 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. As shown in Appendix K.3.4, for the similar 61BT design, these welded plate inserts cause insignificant thermal stresses in the radial and axial directions due to temperature gradients. Therefore, the Appendix K.3.4 values for these stresses are conservatively factored by 2 and used later in Section T.3.6.

1. Basket Stresses Due to Radial Gradient

The temperatures from the thermal analyses discussed in Section T.4 were used to develop bounding polynomial curve-fit equations that give temperatures as a function of radial location. The preliminary temperature gradients were conservatively modified by increasing the temperature in the center of the basket by 50°F and decreasing the temperature at the perimeter of the basket by 50°F. Temperatures between the center of the basket and the perimeter of the basket were modified proportionally to maintain the same basic shape of the temperature distribution. For a given bounding curve, the conservative temperature gradient is mapped onto the basket model in all radial directions to give the largest gradient across the entire diameter of the basket. This gives bounding, conservative basket temperature gradients and thermal stresses, which are used to evaluate the effects of radial thermal expansion in the basket components. Final analyses discussed in Section T.4 were reconciled against the bounding curves described herein, which still govern the stress analysis results.

Figure T.3.4-3 shows the bounding basket radial temperature polynomial curve that gave the highest basket thermal stresses (excluding vacuum drying). The radial temperature distribution curve used in the thermal stress analysis and the corresponding equation shown in Figure T.3.4-3 is labeled ModCase43F. Stress results based on this temperature distribution are used as bounding for all thermal cases except vacuum drying.

In the assessment and reconciliation of the final thermal analyses of Section T.4, it was recognized that the highest thermal stresses resulted for those cases where the maximum basket temperature did not occur at the radial center of the basket. This is due to fuel loading arrangements where the fuel assemblies with the maximum heat load are located away from the center, resulting in the maximum temperature to occur between the radial center of the basket and the perimeter of the basket. This occurs only for the Type 2 basket, which gave the highest thermal stresses. These results were then used as enveloping thermal stresses for both the Type 1 basket and the Type 2 basket.

Vacuum drying condition temperature distributions evaluated for the Type 1 basket and the Type 2 basket, represented in Figure T.3.4-4 and Figure T.3.4-5, respectively, used results that bounds Section T.4 analyses. The radial temperature polynomial curves used were conservatively modified as discussed before to give conservative bounding thermal stresses.

The Section T.4 final temperature distributions and associated temperature gradients are on the order of 10°F lower for the storage and transfer conditions and more than 60°F lower for the vacuum drying conditions. Therefore, the bounding temperature distributions and stresses were maintained.

A three-dimensional finite element model of the basket is used for stress analyses of the basket, using ANSYS [3.11]. This finite element model is essentially the same as that used in Section K.3.4 for the 61BT basket which has an identical geometry for the portion of the basket modeled. As done in Section K.3.4, due to the approximate symmetric nature of the temperature distributions, and for simplicity, only a ¼ model is used in this analysis. Although the temperature gradients do not exhibit perfect symmetry from top to bottom of the basket section, the general distribution is that the inside is hotter than the outside, providing a radial gradient across the basket section. A review of the temperature distributions at the basket section with the hottest temperatures were performed to obtain the largest radial gradient. The analyses then used the largest gradient (center to top, center to bottom, or center to side) as the basis for the analyses to give the highest thermal stresses in the basket. The four-node element SHELL43 was used in the stress analyses.

An elastic stress analysis of the basket structure was conducted for computing the thermal stresses. The nodal temperature distributions based on the bounding polynomial curve-fit equations were applied to the structural models. The shell top or bottom surface stress intensity is the thermal membrane plus bending stress intensity. The maximum Type 1 or Type 2 basket thermal membrane plus bending stress intensity is 14.62 ksi for the bounding storage or transfer condition (excluding vacuum drying). The Type 1 basket maximum thermal membrane plus bending stress intensity is 15.06 ksi for the vacuum drying condition. The Type 2 basket maximum thermal membrane plus bending stress intensity is 16.17 ksi for the vacuum drying condition.

2. Stresses in Outer Box (Wrap) Due to Axial Thermal Gradient

The outer box is hottest near the longitudinal center of the basket and cooler at the top and bottom ends of the basket. This axial gradient will result in unequal thermal expansions at the center compared to the top or bottom end (see Figure T.3.4-2(b)), causing bending stresses in the outer wrap.

<u>-40°F Ambient Off-Normal Storage Condition</u>

Maximum temperature at center = 560°F (envelope of Type 1 or Type 2)
Minimum temperature at top = 310°F (conservative)

α_S = Stainless steel coefficient of thermal expansion = 9.8×10^{-6} in./in.°F at 560°F
α_S = Stainless steel coefficient of thermal expansion = 9.2×10^{-6} in./in.°F at 310°F

L = 19.43 + 2 (0.105) = 19.64 in.

At center, thermal growth, δL_1 = 19.64 (560 - 70) 9.8×10^{-6} = 0.09431 in.
At top, thermal growth, δL_2 = 19.64 (310 - 70) 9.2×10^{-6} = 0.04337 in.

Therefore, plate deflection on either side of box = ½ (0.09431 - 0.04337) = 0.02547 in.

Stresses are calculated in the box side as a plate 19.64" x 164", assuming fixed on all sides (Reference [3.12], 5th Ed., Table 26, Case 8):

a = 164" b = 19.64" a/b = 8.35 $\alpha = 0.0284$ $\beta = 0.5$

Max. deflection $y = \alpha\, wb^4/(Et^3)$ $w = yEt^3 / \alpha\, b^4$ E, at 310°F = 27.0×10^6

At center of long edge, max. stress, $s = \beta\, wb^2 / t^2 = (\beta/\alpha)\,[yEt/b^2]$
$= (0.5/0.0284)\,(0.02547)\,(27.0 \times 10^6)\,(0.105/19.64^2) = 3{,}296$ psi

100°F Ambient Normal Storage Condition

Maximum temperature at center = 670°F (envelope of Type 1 or Type 2)
Minimum temperature at top = 435°F (conservative)

α_S = Stainless steel coefficient of thermal expansion = 9.9×10^{-6} in./in.°F at 670°F
α_S = Stainless steel coefficient of thermal expansion = 9.6×10^{-6} in./in.°F at 435°F

L = 19.43 + 2 (0.105) = 19.64 in.

At center, thermal growth, δL_1 = 19.64 (670 - 70) 9.9×10^{-6} = 0.11666 in.
At top, thermal growth, δL_2 = 19.64 (435 - 70) 9.6×10^{-6} = 0.06882 in.

Therefore, plate deflection on either side of box = ½ (0.11666 - 0.06882) = 0.02392 in.

Stresses are calculated in the box side as a plate 19.64" x 164", assuming fixed on all sides (Reference [3.12], 5th Ed., Table X, Case 41):

a = 164" b = 19.64" a/b = 8.35 $\alpha = 0.0284$ $\beta = 0.5$

Max. deflection y = α wb4 /(Et3) w = yEt3 / α b4 E, at 435°F = 26.3 x 106

At center of long edge, max. stress, s = β wb2 / t2 = (β/α) [yEt/b2]
= (17.606) (0.02392) (26.3x106) (0.105/19.642) = 3,095 psi

117°F Ambient Off-Normal Storage Condition

Maximum temperature at center = 675°F (envelope of Type 1 or Type 2)
Minimum temperature at top = 458°F (conservative)

α_S = Stainless steel coefficient of thermal expansion = 10.0×10^{-6} in./in.°F at 675°F
α_S = Stainless steel coefficient of thermal expansion = 9.6×10^{-6} in./in.°F at 458°F

L = 19.43 + 2 (0.105) = 19.64 in.

At center, thermal growth, δL_1 = 19.64 (675 - 70) 10.0×10^{-6} = 0.11882 in.
At top, thermal growth, δL_2 = 19.64 (458 - 70) 9.6×10^{-6} = 0.07316 in.

Therefore, plate deflection on either side of box = ½ (0.11882 - 0.07316) = 0.02283 in.

Stresses are calculated in the box side as a plate 19.64" x 164", assuming fixed on all sides (Reference 3.12, 5th Ed., Table 26, Case 8):

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

Max. deflection y = α wb4 /(Et3) w = yEt3 / α b4 E, at 458°F = 26.15 x 106

At center of long edge, max stress, s = β wb2 / t2 = (β/α) [yEt/b2]
= (17.606) (0.02283) (26.15x106) (0.105/19.642) = 2,954 psi

0°F Ambient Normal Transfer Condition

Maximum temperature at center = 660°F (envelope of Type 1 or Type 2)
Minimum temperature at top = 448°F (for –40°F ambient case, conservative)

α_S = Stainless steel coefficient of thermal expansion = 9.9×10^{-6} in./in.°F at 660°F
α_S = Stainless steel coefficient of thermal expansion = 9.6×10^{-6} in./in.°F at 448°F

L = 19.43 + 2 (0.105) = 19.64 in.

At center, thermal growth, δL_1 = 19.64 (660 - 70) 9.9×10^{-6} = 0.11472 in.
At top, thermal growth, δL_2 = 19.64 (448 - 70) 9.6×10^{-6} = 0.07127 in.

Therefore, plate deflection on either side of box = ½ (0.11472 - 0.07127) = 0.02173 in.

Stresses are calculated in the box side as a plate 19.64" x 164", assuming fixed on all sides (Reference 3.12, 5th Ed., Table 26, Case 8):

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

Max. deflection y = α wb4 /(Et3) w = yEt3 / α b4 E, at 448°F = 26.1 x 106

At center of long edge, max stress, s = β wb2 / t2 = (β/α) [yEt/b2]
= (0.5/0.0284) (0.02173) (26.1x106) (0.105/19.642) = 2,718 psi

117°F Ambient Off-Normal Transfer Condition (Bounds the 100°F Ambient Case)

Maximum temperature at center = 715°F (envelope of Type 1 or Type 2)
Minimum temperature at top = 510°F (for 100°F ambient case, conservative)

α_S = Stainless steel coefficient of thermal expansion = 10.0×10^{-6} in./in.°F at 715°F
α_S = Stainless steel coefficient of thermal expansion = 9.7×10^{-6} in./in.°F at 510°F

L = 19.43 + 2 (0.105) = 19.64 in.

At center, thermal growth, δL_1 = 19.64 (715 - 70) 10.0×10^{-6} = 0.12668 in.
At top, thermal growth, δL_2 = 19.64 (510 - 70) 9.7×10^{-6} = 0.08382 in.

Therefore, plate deflection on either side of box = ½ (0.12668 - 0.08382) = 0.02143 in.

Stresses are calculated in the box side as a plate 19.64" x 164", assuming fixed on all sides (Reference [3.12], 5th Ed., Table 26, Case 8):

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

Max. deflection y = α wb4 /(Et3) w = yEt3 / α b4 E, at 510°F = 25.8 x 106

At center of long edge, max stress, s = β wb2 / t2 = (β/α) [yEt/b2]
= (17.606) (0.02143) (25.8x106) (0.105/19.642) = 2,650 psi

<u>Vacuum Drying Condition</u> (bounding for Type 1 at 29 hours)

Maximum temperature at center = 705°F (conservative)
Minimum temperature at top = 350°F (conservative)

α_S = Stainless steel coefficient of thermal expansion = 10.0×10^{-6} in./in.°F at 705°F
α_S = Stainless steel coefficient of thermal expansion = 9.3×10^{-6} in./in.°F at 350°F

L = 19.43 + 2 (0.105) = 19.64 in.

At center, thermal growth, δL_1 = 19.64 (705 - 70) 10.0×10^{-6} = 0.12471 in.
At top, thermal growth, δL_2 = 19.64 (350 - 70) 9.3×10^{-6} = 0.05114 in.

Therefore, plate deflection on either side of box = ½ (0.12471 - 0.05114) = 0.03679 in.

Stresses are calculated in the box side as a plate 19.64" x 164", assuming fixed on all sides (Reference [3.12], 5th Ed., Table 26, Case 8):

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

Max. deflection y = α wb4 /(Et3) w = yEt3 / α b4 E, at 350°F = 26.75 x 106

At center of long edge, max stress, s = β wb2 / t2 = (β/α) [yEt/b2]
= (17.606) (0.03679) (26.75x106) (0.105/19.642) = 4,716 psi

3. Stresses in Outer Box due to Thermal Expansion of Inner Boxes and Aluminum Plates Thickness

<u>Enveloping Ambient Condition (Type 1 and Type 2 Baskets, Excludes Vacuum Drying)</u>

Max. basket temp. (at middle section) = 715°F (envelope of Type 1 or Type 2)

Thermal growths and stresses in the 3 x 3 outer box will be higher due to two poison aluminum thicknesses.

α_S = Stainless steel coefficient of thermal expansion = 10.0×10^{-6} in./in.°F at 715°F
α_a = Aluminum coefficient of thermal expansion = 14.5×10^{-6} in./in.°F at 715°F
E = Stainless steel modulus of elasticity = 24.7×10^{6} psi at 715°F

Tensile stress in outer box will be generated by the differential thermal growth of outer and inner plates due to higher aluminum coefficient of thermal expansion.

Differential thermal growth, δL = 2 (0.31) (715 - 70) [αa - αs]
= 2 (0.31) (715-70) [14.5 × 10-6 – 10.0 × 10-6] = 0.00180 in.

Outer box inside length, L = 6 (3) + 6 (0.135) + 2 (0.31) = 19.43 in.

Assuming conservatively that outer wrap elongates by δL ,

Tensile Stress = 0.00180 (24.7×10^{6}) / 19.43 = 2,288 psi

<u>Enveloping Vacuum Drying Condition (Type 1 and Type 2 Baskets)</u>

Max. basket temp. (at middle section) = 750°F (envelope of Type 1 or Type 2)

Thermal growths and stresses in 3 x 3 outer box will be higher due to two poison aluminum thicknesses.

αS = Stainless steel coefficient of thermal expansion = 10.0 × 10-6 in./in.°F at 750°F
αa = Aluminum coefficient of thermal expansion = 14.7 × 10-6 in./in.°F at 750°F
E = Stainless steel modulus of elasticity = 24.5 × 106 psi at 750°F

Tensile stress in outer box will be generated by the differential thermal growth of outer and inner plates due to higher aluminum coefficient of thermal expansion.

Differential thermal growth, δL = 2 (0.31) (750 - 70) [αa - αs]
= 2 (0.31) (750-70) [14.7 × 10-6 – 10.0 × 10-6] = 0.001982 in.

Outer box inside length, L = 6 (3) + 6 (0.135) + 2 (0.31) = 19.43 in.

Assuming conservatively that outer wrap elongates by δL ,

Tensile Stress = 0.001982 (24.5×10^{6}) / 19.43 = 2,499 psi

4. Stresses in Outer Box Due to Thermal Expansion of Aluminum Plates Length (Vacuum Drying Only)

Similar to the 61BT design, as shown in Section K.3.4, for all conditions except the vacuum drying condition, the aluminum plates are free to grow along their length without restraint. Therefore, thermal stresses in the outer box due to this interference are calculated for the vacuum drying condition only.

Maximum basket temperature (At middle section) = 750°F (conservative)

Differential thermal growth of aluminum and steel = $19.43\ (750 - 70)\ [14.7 \times 10^{-6} - 10.0 \times 10^{-6}]$
= 0.06210 in.

Therefore, the aluminum plate is not free to grow under the condition of minimum gap, which is assumed to be the same as Section K.3.4 and is equal to 0.05". The two steel plates will deflect by about 0.06210 - 0.05 = 0.0121". Assuming conservatively that aluminum plate has zero deformation, each steel plate will deflect by 0.0061" at the aluminum plate location (x = 6.43" from end). The deflection at center is estimated by assuming the plate as a beam with fixed ends, span L = 19.43",

Approximately (using same equations as Section K.3.4),

$$y = W/(48\ EI)\ [3Lx^2 - 4\ x^3] = W/(48\ EI)\ [3\ (19.43)\ (6.43)^2 - 4\ (6.43)^3] = 0.0061"$$

$$W/EI = 0.0061\ (48) / 1346.6 = 0.0002174$$

Deflection at center, $y_{max} = WL^3/(192\ EI) = 0.0002174\ (19.43)^3 / 192 = 0.008306"$

Bending stress in steel plate is estimated by assuming the plate as a beam with fixed ends, span L = 19.43", thickness = 0.105" and deflection at center (conservative) y = 0.00831 in.

$E = 24.5 \times 10^6$ psi

Max. deflection, $y = W\ L^3 /(192\ EI)$
$W = 192\ y\ EI/L^3$

Max. M = WL/8

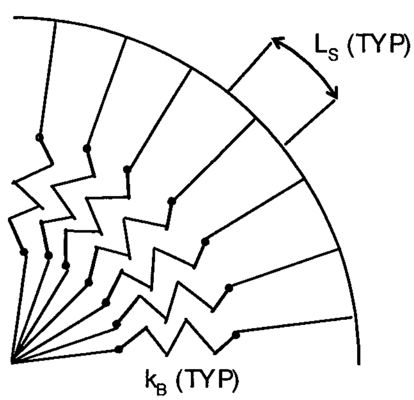
Max. bending stress $= MC/I = WLC/8I = 192\ y\ E\ I\ LC/(L^3 \times 8I) = 24\ y\ EC/L^2$
= 24 (0.00831) (24.5 x106) (0.0525/19.432) = 680 psi

5. Stresses in Basket and Canister Due to Potential Thermal Expansion Radial Interference (Vacuum Drying Only)

Preliminary thermal expansion analyses of the 61BTH basket were performed considering bounding temperatures. These evaluations produced a radial interference between the basket and the canister of 0.025 inches. As shown in Section T.3.4 the gap between the shell and the basket is adequate and no interference is expected. However, the evaluation in this section conservatively assumes an interference of 0.025 inches. The portion of this displacement absorbed by the basket and the portion absorbed by the canister are dependent on the relative stiffness (or flexibility) of the basket compared to the canister. The following calculations are performed for two bounding sets of assumptions, which for one case gives bounding basket stresses, and for the other case gives bounding canister stresses. The calculated stresses are membrane stresses, which can be conservatively added directly to other stress intensity values.

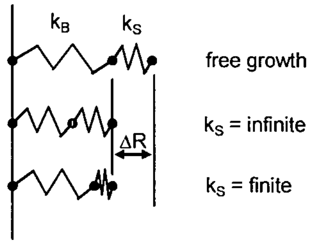
The following calculations assume uniform radial stiffness springs to represent the radial stiffness of the basket. Each radial basket spring is equal to k_B, where k_B is approximated as the in-plane radial stiffness of a radial plate from the center of the basket to the perimeter of the basket. The stiffness of k_B is represented as AE/L where 2 bounding sets of values for A, E, and L are chosen to maximize stresses in the basket for one case and to maximize stresses in the shell for the other case. Seven basket radial springs per quadrant (see sketch below) are assumed to approximate the locations where the basket plates line up with the canister shell. As the basket expands and interferes with the canister shell, the shell deflects under the applied radial load which induces hoop stresses in the shell. At each basket spring, a tributary length of the shell, L_S, acts as a shell spring resisting the growth of the basket. Because the basket rails tend to distribute the load, the basket force on the shell is approximated as a pressure load where the force per unit length is equal to the pressure load, P, times L_S. The change in radius, ΔR, is equal to $PR^2 / (E\ t)$. Using substitution, the tributary shell radial stiffness, k_S, or $(P\ L_S)/\Delta R$, is equal to $L_S\ E\ t / R^2$.

Sketch of quadrant of basket/shell interference representation:



Vacuum Drying Thermal Interference Stress (Bounding Case for Basket)

$\varepsilon_{Total} = \Delta R / R$



$R =$	33	in
$\Delta R =$	(0.30 - 0.25) / 2	
$\Delta R =$	0.025	in
$\varepsilon_{Total} =$	7.5758E-04	in/in

Basket k = A E / L (effective radial stiffness of 1 basket plate spring)

$A_B =$	2 (0.12)	in^2 (per unit length, conservative for basket)
$A_B =$	0.24	in^2 (per unit length)
$E_B =$	28300000	psi (upper bound, conservative for basket)
$L_B =$	33	in (upper bound, conservative for basket)

$f_B = 1 / k_B =$ 4.8587E-06 lb/in (flexibility of tributary basket tube)

Shell $k = L_S E t / R^2$ (effective radial stiffness of shell tributary length)

$t =$	0.5	in
$E_S =$	27300000	psi (lower bound, conservative for basket)
$L_S =$	$2 \pi R / (4 (7))$	(approximate, based on 7 basket plate springs per shell quadrant)
$L_S =$	7.405	in

$f_S = 1 / k_S =$ 1.0774E-05 lb/in (radial flexibility of tributary shell)

$f_{TOT} = f_B + f_S =$ 1.5632E-05 lb/in (total flexibility tributary basket/shell)

$f_B / f_{TOT} =$ 0.3108 (fraction of displacement taken by basket)

$f_S / f_{TOT} =$ 0.6892 (fraction of displacement taken by shell)

Basket Strain & Stress

$\varepsilon_B = \varepsilon_{Total} f_B / f_{TOT}$

$\varepsilon_B =$ 2.3546E-04 in/in

$\varepsilon_B E_B =$ 6664 psi

Shell Strain & Stress

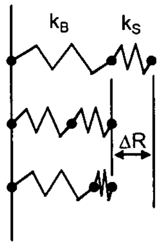
$\varepsilon_S = \varepsilon_{Total} f_S / f_{TOT}$

$\varepsilon_S =$ 5.2211E-04 in/in

$\varepsilon_S E_S =$ 14254 psi

Vacuum Drying Thermal Interference Stress (Bounding Case for Shell)

$\varepsilon_{Total} = \Delta R / R$



R =	33	in
ΔR =	(0.30 - 0.25) / 2	
ΔR =	0.025	in
ε_{Total} =	7.5758E-04	in/in

Basket k = A E / L (effective radial stiffness of 1 basket plate spring)

A_B =	2 (0.105+0.135)+0.31	in^2 (per unit length, conservative for shell)
A_B =	0.79	in^2 (per unit length)
E_B =	24450000	psi (lower bound, conservative for basket)
L_B =	29.34	in (lower bound, conservative for shell)

$f_B = 1 / k_B =$ 1.519E-06 lb/in (flexibility of tributary basket tube)

Shell k = L_S E t / R^2 (effective radial stiffness of shell tributary length)

t =	0.5	in
E_S =	27600000	psi (upper bound, conservative for basket)
L_S =	$2 \pi R / (4 (7))$	(approximate, based on 7 basket plate springs per shell quadrant)
L_S =	7.405	in

$f_S = 1 / k_S =$ 1.0656E-05 lb/in (radial flexibility of tributary shell)

$f_{TOT} = f_B + f_S =$ 1.2175E-05 lb/in (total flexibility tributary basket/shell)

$f_B / f_{TOT} =$ 0.1248 (fraction of displacement taken by basket)

$f_S / f_{TOT} =$ 0.8752 (fraction of displacement taken by shell)

Basket Strain & Stress

$\varepsilon_B = \varepsilon_{Total} f_B / f_{TOT}$

$\varepsilon_B =$ 9.4514E-05 in/in

$\varepsilon_B E_B =$ 2311 psi

Shell Strain & Stress

$\varepsilon_S = \varepsilon_{Total} f_S / f_{TOT}$

$\varepsilon_S =$ 6.6306E-04 in/in

$\varepsilon_S E_S =$ 18301 psi

Based on the above calculations the maximum basket stress intensity due to the potential vacuum drying interference is approximately 6.7 ksi and the maximum canister shell stress intensity is approximately 18.3 ksi.

6. *Summary of Thermal Stresses in Basket*

The table below summarizes and combines basket thermal stresses due to different thermal growth considerations. It should be noted that this combination is conservative, since the maximum stress intensities due to each individual load are added, irrespective of their location. Actually, these maximum stress intensities occur at different locations of the basket.

Basket - Bounding Thermal Stress Intensities

Loading Condition	Radial Gradient Stress(2) (psi)	Axial Gradient Stress (psi)	Aluminum Thickness Growth Stress(2) (psi)	Aluminum Length Growth Stress (psi)	Canister Interference Stress (psi)	Total Stress (psi)
-40°F Amb. Storage (off-normal)	14,622	3,296	2,288	0	0	20,206
100°F Amb. Storage (normal)	14,622	3,095	2,288	0	0	20,005
117°F Amb. Storage (off-normal)	14,622	2,954	2,288	0	0	19,864
0°F Amb. Transfer (normal)	14,622	2,718	2,288	0	0	19,628
117°F(1) Amb. Transfer (off-normal)	14,622	2,650	2,288	0	0	19,560
Vacuum Drying (normal)	16,168	4,716	2,499	680	6664	30,727

Notes: 1. Conservative hand calculations make this bounding for the 100°F ambient case.
2. For all storage and transfer conditions, a bounding stress is reported.

B. Thermal Stress Analysis of the Stainless Steel (SST) 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.

The limiting temperature distributions (or polynomial curve-fit equations) discussed above in Section T.3.4.4.3A for the storage, transfer and vacuum drying conditions are used for the evaluation of the SST rails. Similar to the method used for the basket thermal stresses, other conditions based on actual radial distributions from Section T.4 were also evaluated but did not result in higher thermal stresses than those for the bounding temperature distribution equations. Only the limiting thermal stresses for the basket SST rails are presented.

A three-dimensional finite element model of a basket R45 SST rail is used for the thermal stress analysis, using ANSYS (Reference 3.11). This finite element model is the same that as described in Section K.3.4 for the 61BT basket SST rail, which has geometry identical to the SST basket rail modeled. The four-node element SHELL43 was used in the stress analyses. An elastic stress analysis of the basket rail structure was conducted for computing the thermal stresses. The nodal temperature distributions based on the bounding polynomial curve-fit equations were applied to the structural models.

The maximum Type 1 or Type 2 basket thermal membrane plus bending stress intensity is 1.40 ksi for the bounding storage or transfer condition (excluding vacuum drying).

The bounding thermal stress intensity for the vacuum drying condition is 2.21 ksi. Conservatively adding the basket stress due to potential interference with the canister (approximately 6.67 ksi, see Section 6.5), gives a total vacuum drying thermal stress intensity of approximately 8.88 ksi.

The following table summarizes bounding thermal stresses for the Type 1 and Type 2 basket SST rails:

Basket SST Rails - Bounding Thermal Stresses

Loading Condition	Radial Gradient Stress (psi)(1)
-40°F Amb. Storage (off-normal)	1,403
100°F Amb. Storage (normal)	1,403
117°F Amb. Storage (off-normal)	1,403
0°F Amb. Transfer (normal)	1,403
100°F Amb. Transfer (normal)	1,403
117°F Amb. Transfer (off-normal)	1,403
Vacuum Drying (normal)	8,877(2)

Notes:

1. For all storage and transfer conditions, a bounding stress is reported.
2. Conservatively includes basket stress due to interference with canister.

At 25°C (77°F):

At 60°C (140°F):

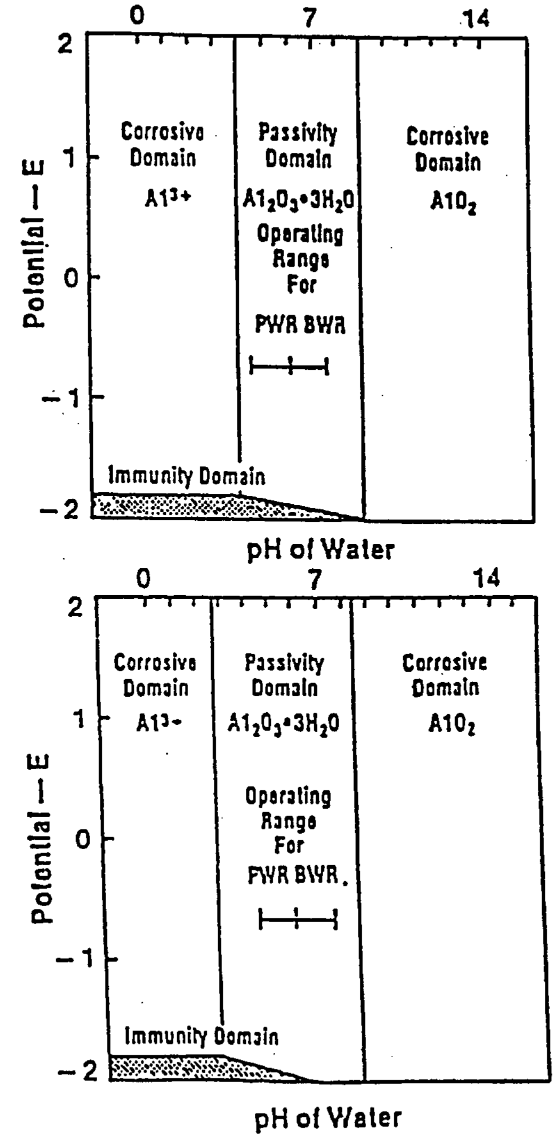


Figure T.3.4-1
Potential Versus pH Diagram for Aluminum-Water System

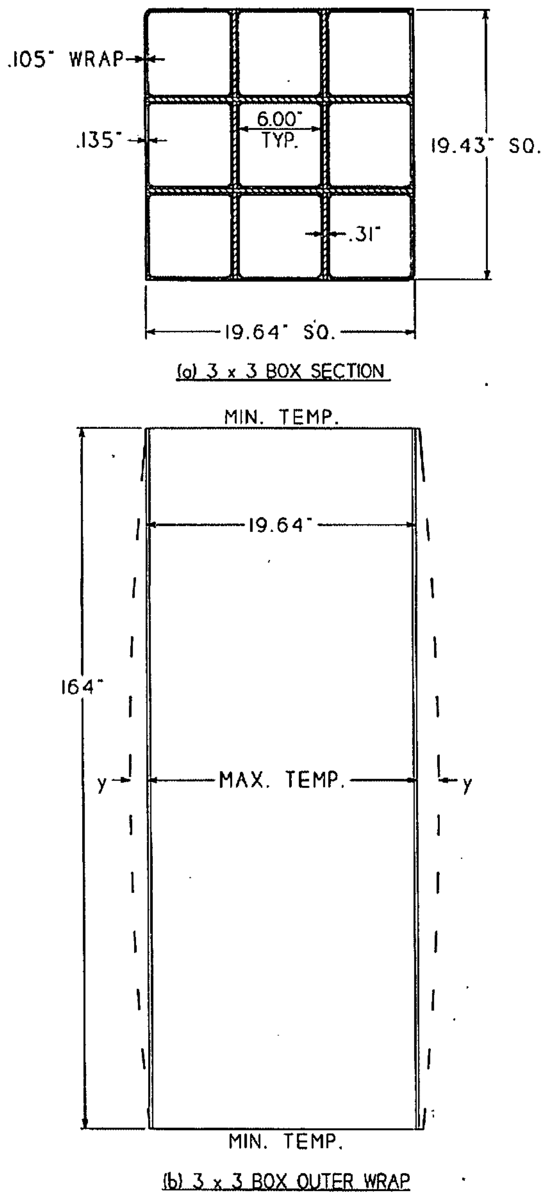


Figure T.3.4-2
Thermal Stress Analysis Geometry

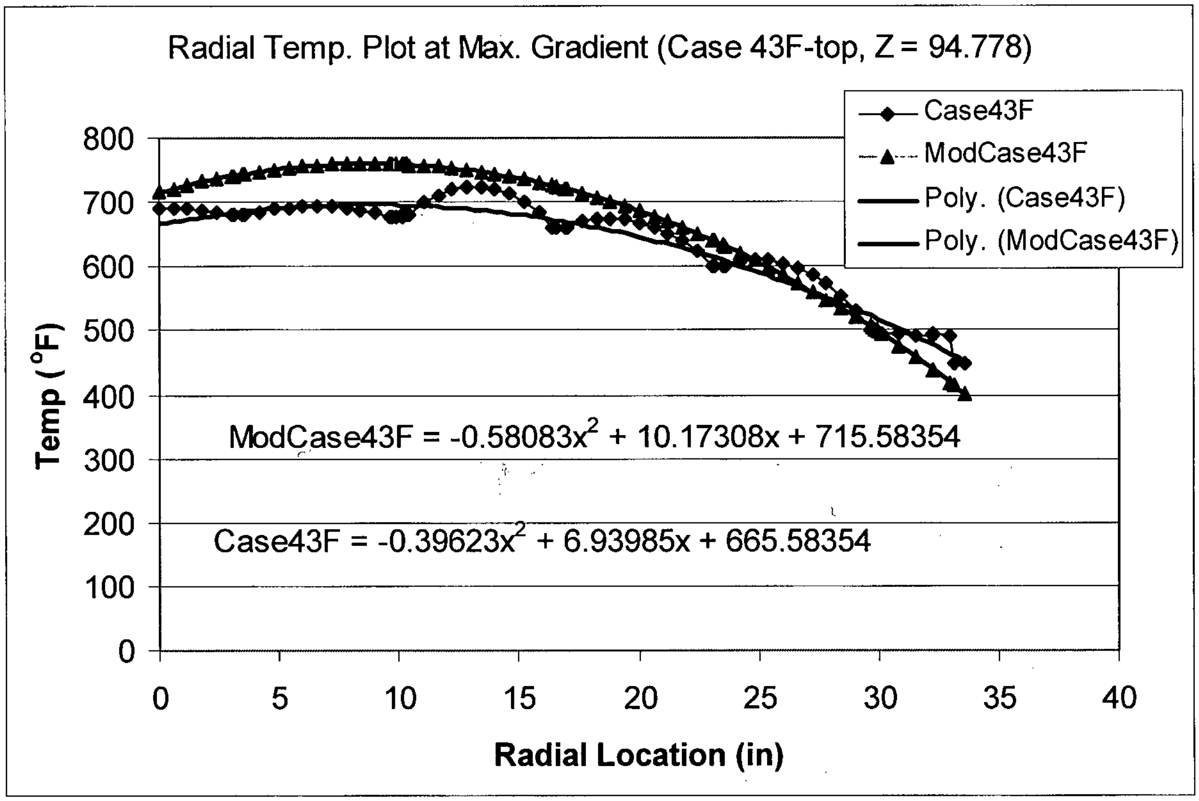


Figure T.3.4-3
Bounding Basket Radial Temperature Polynomial Curve

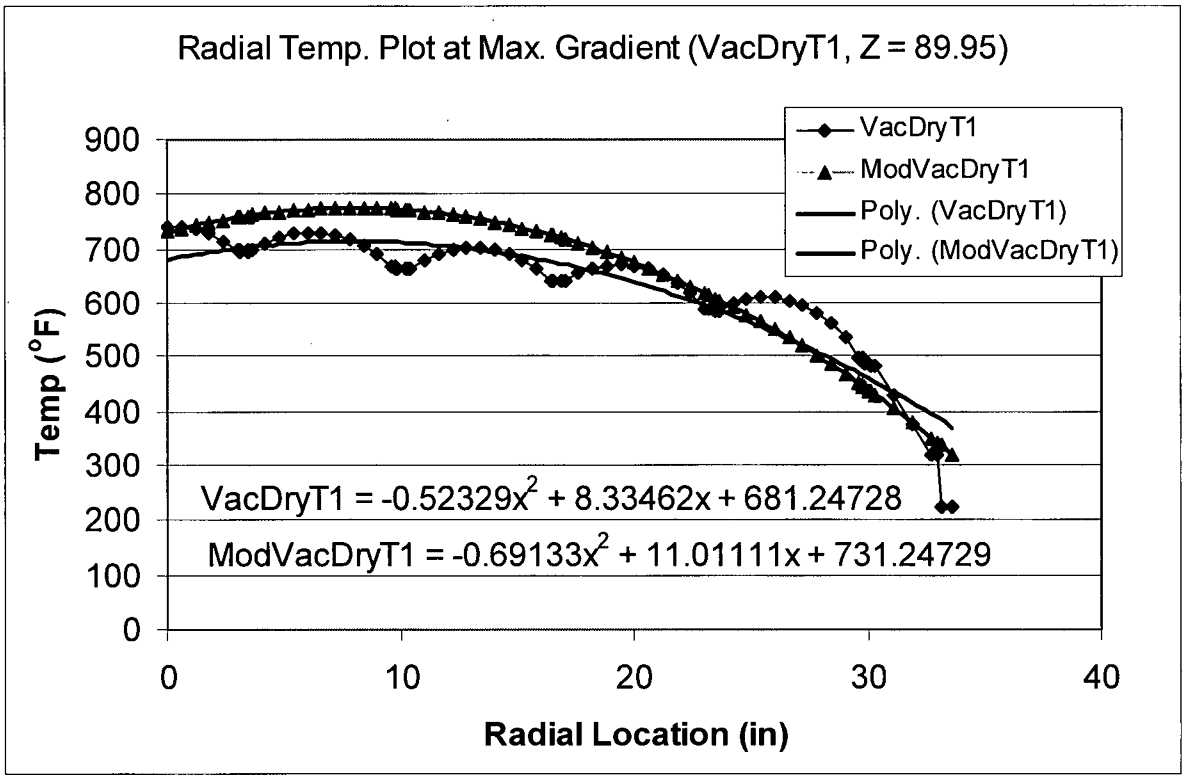


Figure T.3.4-4
Type 1 Basket Radial Temperature Polynomial Curves – Vacuum Drying Conditions

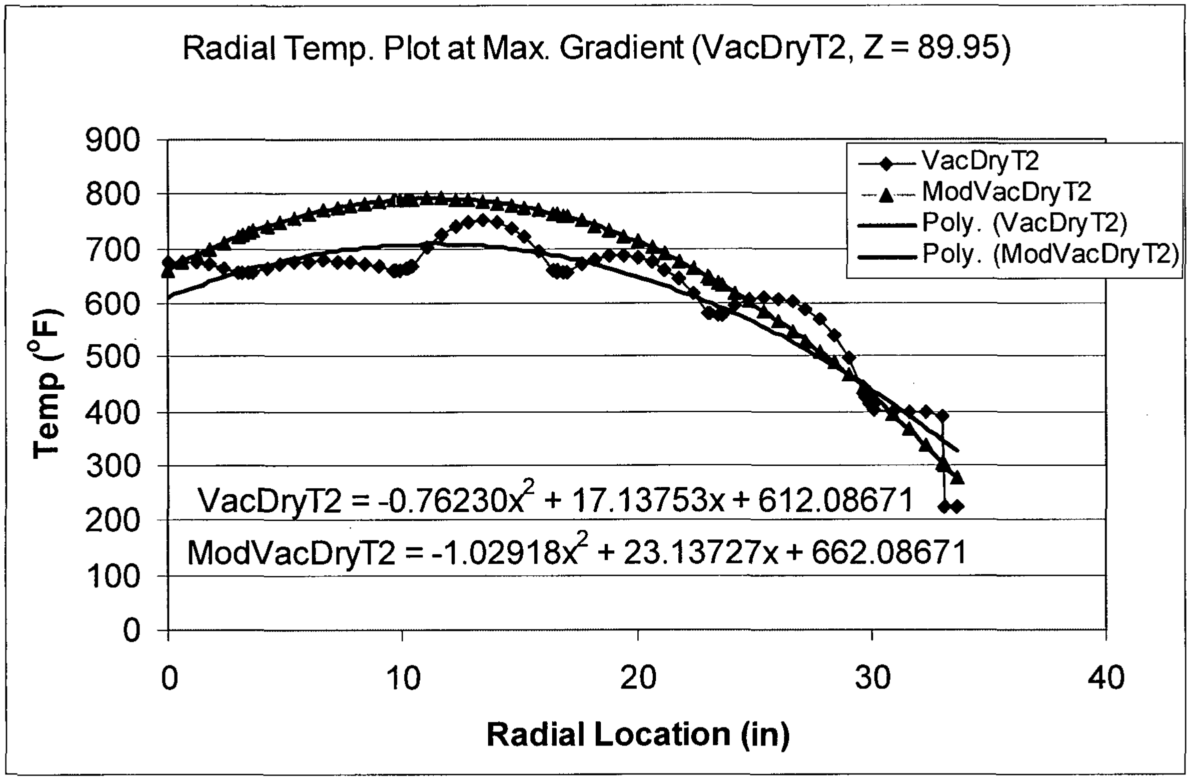


Figure T.3.4-5
Type 2 Basket Radial Temperature Polynomial Curves – Vacuum Drying Conditions

T.3.5

Proprietary Information withheld from pages T.3.5-1 through T.3.5-15 under 10 CFR 2.390

Table T.3.5-5
Summary of Stress Results for 75g Side Drop

	7x7	8x8	8x8	8x8	8x8	9x9	10x10	7x7	8x8	8x8	8x8	8x8	9x9	10x10	8x8	8x8
GE Designation	GE1, GE2, GE3	GE4	GE5	GE8	GE9, GE10	GE11, GE13	GE12, GE14	ENC-IIIA	ENC-III	ENC-VA, ENC-VB	FANP 8x8-2	FANP 9x9-2	Siemens-QFA	Atrium-10	XXX-RCN	STD GE-4
Max Bending Stress, S_b (psi)	60,010	58,763	65,319	65,319	65,319	62,888	62,225	56,478	56,478	55,968	63,374	68,882	73,184	67,565	58,763	58,763
Internal Pressure (psi)	2365	2369	3178	3273	3230	2396	2310	2365	2411	3276	3180	2278	2448	2330	3326	3135
Axial $Stress_{press}$ (psi)(4)	10.661	8634	12,156	12,520	12,355	9691	9302	9586	9773	11,382	10,985	8163	10,524	10,142	12,122	11,426
Combined Stress(1) (psi)	70,671	67,397	77,475	77,839	77,674	72,579	71,527	66,064	66,251	67,350	74,359	77,045	83,708(4)	77,707	70,885	70,189
Yield Stress at Temperature(2) (psi)	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834	93,834

Notes:

(1) Includes 0.0027 inch reduction in cladding thickness to account for oxidation.

(2) Temperature of 495.2°F used for stress allowable at the location where maximum stress occurs.

(3) Axial Stress due to pressure = p x D_{avg} / 4t

(4) Dynamic analysis performed in Appendix T.3.5.4 calculates maximum combined stress of 76,768 psi.

Proprietary Information withheld from pages T.3.5-17 through T.3.5-19 under 10 CFR 2.390

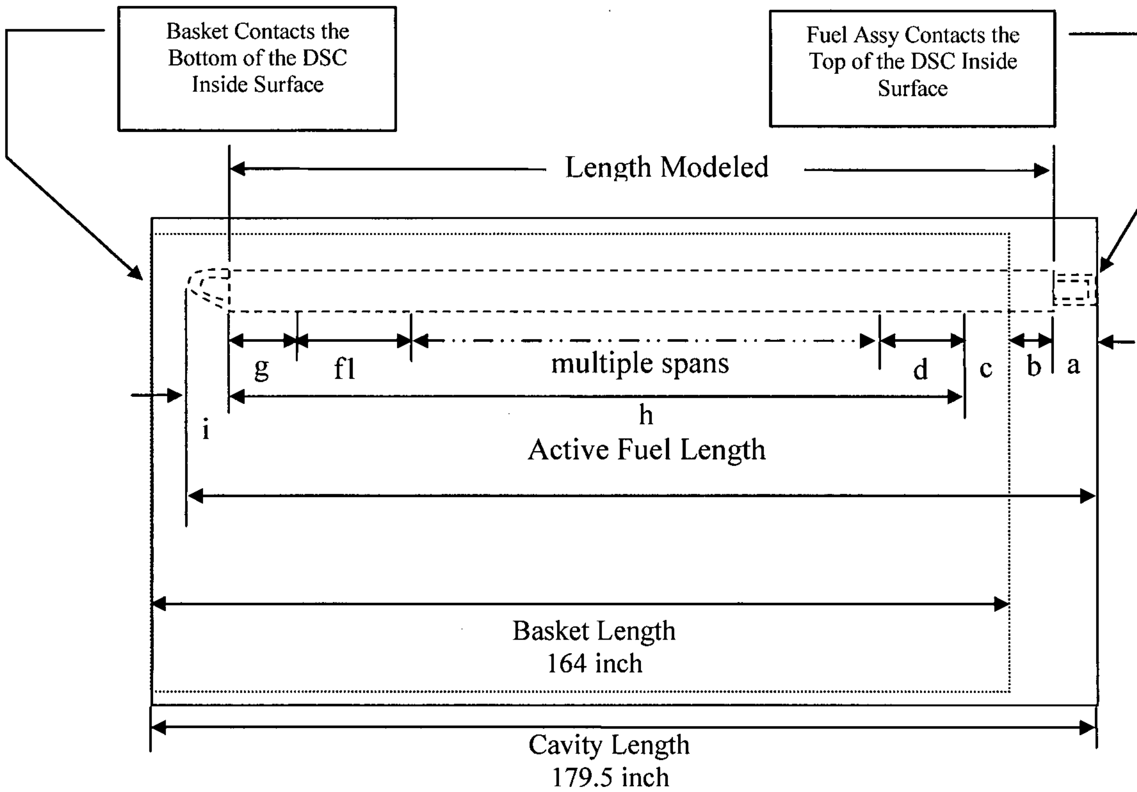


Figure T.3.5-1
Location of Fuel Assemblies vs. Basket during 75g Side Drop

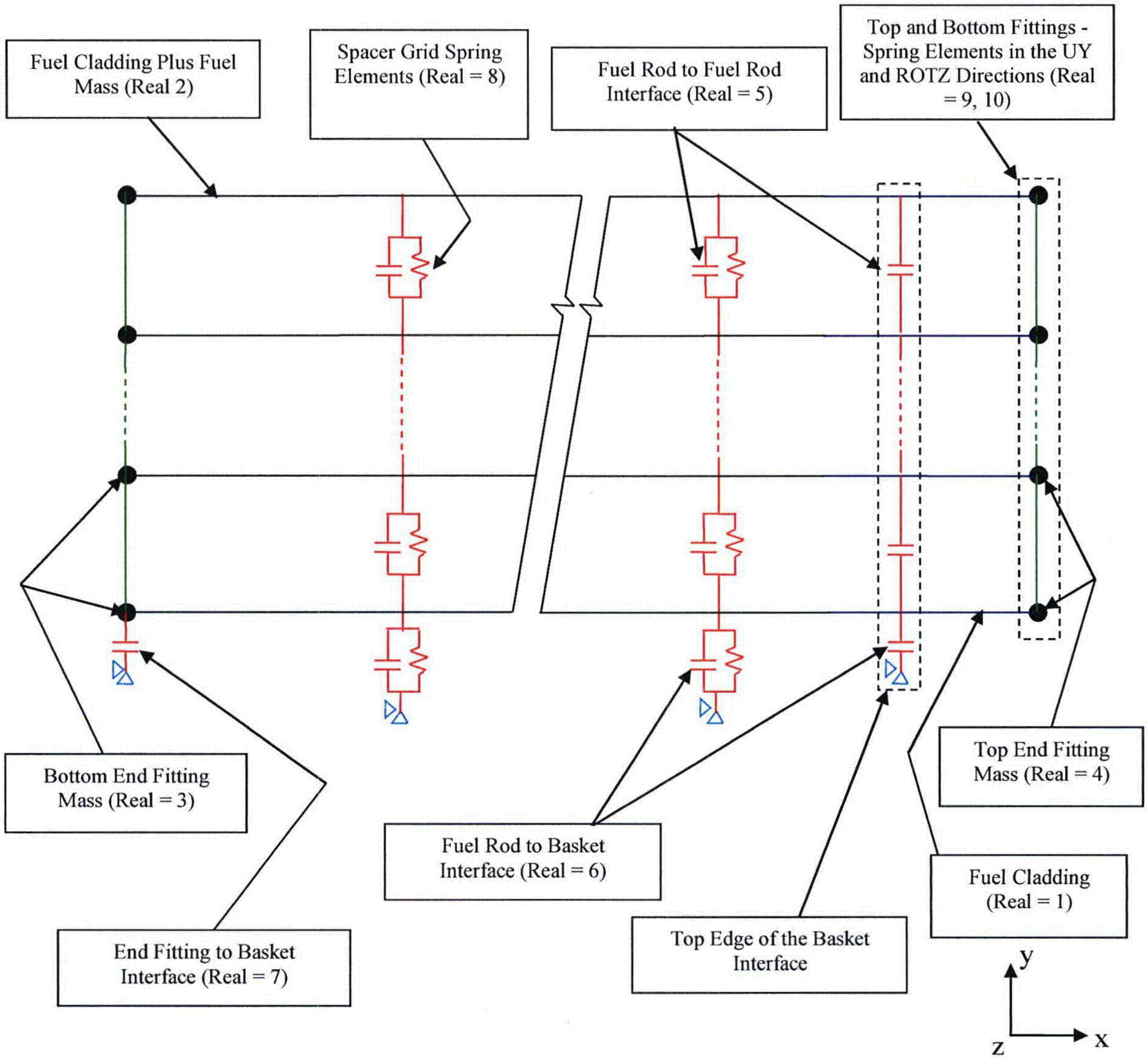


Figure T.3.5-2
Finite Element Model for Side Drop Analysis

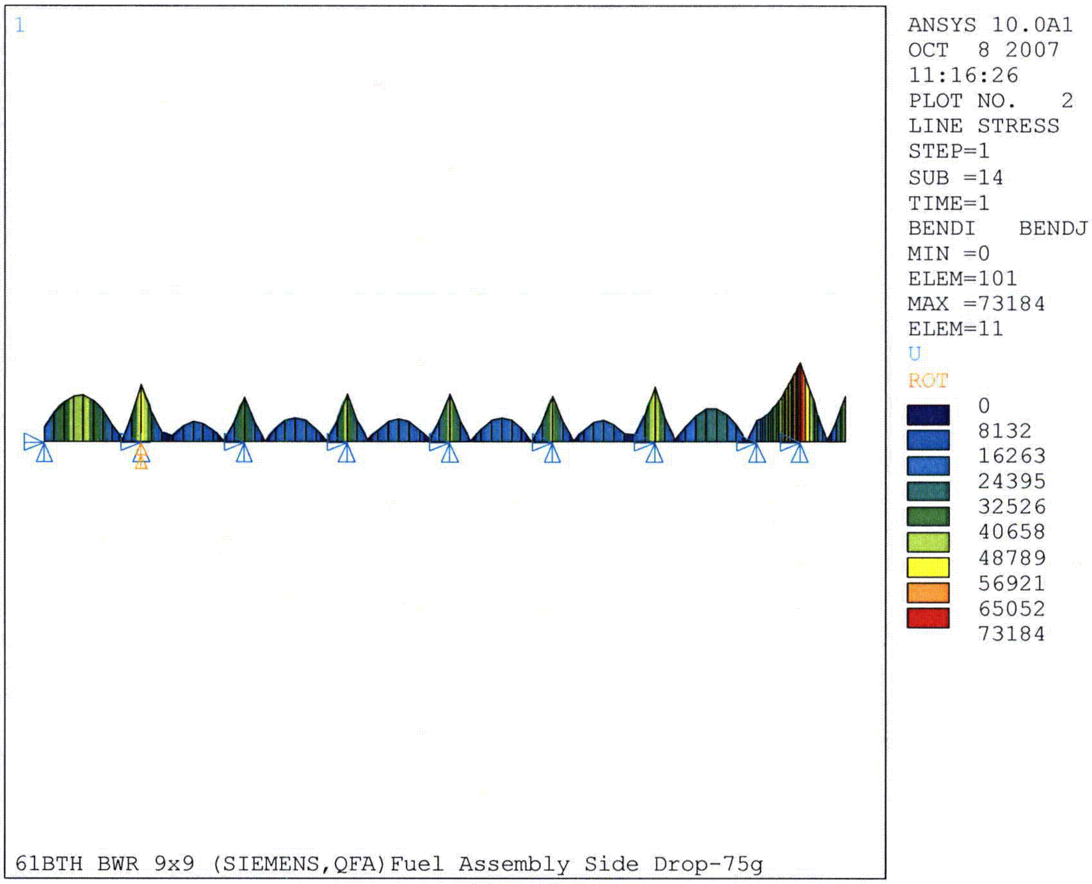


Figure T.3.5-1
BWR 9x9 (Siemens, QFA) Fuel Assembly - Bending Stress at 75g (Side Drop)
(Bottom-most Rod)

Proprietary Information withheld under 10 CFR 2.390

FIGURE DELETED

Figure T.3.5-2
Bottom End Drop Model Shown with Initial Bowing of 0.015 in., – BWR 9x9 Siemens, QFA

Proprietary Information withheld under 10 CFR 2.390

FIGURE DELETED

Figure T.3.5-3
BWR 10x10 (Atrium-10)- Axial Stress at 0° and 180°(Span 3)
(Top End Drop Model)

Proprietary Information withheld under 10 CFR 2.390

FIGURE DELETED

Figure T.3.5-4
BWR 9x9 (Siemens, QFA) - 0.039 Inch Bowing –
Lateral Displacement at the Midspans of the Bottom Three Spans
(Bottom End Drop Model)

FIGURE DELETED

Figure T.3.5-5
BWR 9x9 (Siemens, QFA) - 0.039 Inch Bowing - Axial Stress at 0° (Span 1)
(Bottom End Drop Model)

FIGURE DELETED

Figure T.3.5-6
BWR 9x9 (Siemens, QFA) -0.039 Inch Bowing - Axial Plastic Strain at 0° (Span 1)
(Bottom End Drop Model)

Proprietary Information withheld from pages T.3.5-31 through T.3.5-33 under 10 CFR 2.390

T.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. Design event Types III and IV cover a range of postulated accident events and are addressed in Section 8.2. The purpose of this section of the Appendix is to present the structural analyses for normal and off-normal operating conditions for the NUHOMS®-61BTH system using a format similar to the one used in Section 8.1 for analyzing the NUHOMS®-52B system.

T.3.6.1 Normal Operation Structural Analysis

Table T.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 T.3.6.1.1.

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

T.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 T.3.2-1 shows the weights of various components of the NUHOMS®-61BTH 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®-61BTH DSC for the storage and transfer mode are presented in Table T.4-16 and Table T.4-20 for normal and off-normal conditions, respectively.

C. Design Basis Thermal Loads

The temperature distribution for the DSC shell assembly for the normal conditions is presented in Section T.4 and the resulting thermal loads are addressed in Section T.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 or HSM-H, and (2) loads associated with loading the DSC into (and unloading the DSC from) the HSM or HSM-H. These handling loads are described in Section 8.1.1.1D.

Based on the surface finish and the contact angle of the DSC support rails inside the HSM or HSM-H described in Chapter 4, 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 27,005 lbs, calculated as follows, for Type 2 DSC:

$$P = \frac{0.25\ W}{\cos\theta} = 0.29\ W \quad = 0.29(93{,}120\ \text{lbs}) = 27{,}005\ \text{lbs (Type 2 DSC)}$$

Where:

P = Push/Pull Load

W = Loaded DSC Weight ≈ 93,120 lbs (See Table T.3.2-1 for Type 2 DSC)

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. 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, a live load of 200 pounds per square foot is conservatively selected to envelope all postulated live loads acting on the HSM or HSM-H, 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.

T.3.6.1.2 Dry Shielded Canister Analysis

The standardized NUHOMS®-61BTH DSC shell assembly is analyzed for the normal, off-normal and postulated accident load conditions using two basic ANSYS [3.11] finite element models for each type of DSC: 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.

These models are used to evaluate stresses in the NUHOMS®-61BTH 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 T.3.6-4 and Table T.3.6-5 summarizes the resulting stresses for normal operating loads for the Type 1 DSC and the Type 2 DSC, respectively.

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 TC, the weight of the fuel and the bottom end components is transferred to the TC by bearing through the inner cover plate, shield plug and outer bottom cover plate. When in the horizontal position, the DSC is in the TC or in the HSM or HSM-H. 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 TC) and ± 30° (when in the HSM or HSM-H) from the bottom centerline of the DSC. This is shown schematically in Figure 8.1-13.

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 T.3.6.1.3.1. 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 T.3.6-4 for the Type 1 DSC and Table T.3.6-5 for the Type 2 DSC.

B. DSC Normal Operating Design Basis Pressure Analysis

The 61BTH DSC shell assembly analytical models shown in Figure 8.1-14a and Figure 8.1-14b are used for the normal operating design pressure analyses. The calculated maximum internal pressures for the NUHOMS®-61BTH DSC are shown in Table T.4-16. The resulting maximum stress intensities are reported in Table T.3.6-4 for the Type 1 DSC and Table T.3.6-5 for the Type 2 DSC.

C. DSC Normal Operating Thermal Stress Analysis

The thermal analyses of the DSC for the various conditions, as presented in Section T.4, 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 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 either A-36 carbon steel or SA 240 Type 304 stainless 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 T.3.6-4 for the Type 1 DSC and Table T.3.6-5 for the Type 2 DSC.

D. DSC Operational Handling Load Analysis

To load the DSC into the HSM or HSM-H, the DSC is pushed out of the transfer cask using a hydraulic ram. The applied force from the hydraulic ram, 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 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 or HSM-H, 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.

The controlling stresses from these analyses are tabulated in Table T.3.6-4 for the Type 1 DSC and Table T.3.6-5 for the Type 2 DSC.

E. Evaluation of the Results

The maximum calculated DSC shell stresses induced by normal operating load conditions are shown in Table T.3.6-4 for the Type 1 DSC and Table T.3.6-5 for the Type 2 DSC. The calculated stresses for each load case are combined in accordance with the load combinations presented in Table T.2-11. The resulting stresses for the controlling load combinations are reported in Section T.3.7.12 with the ASME Code allowable stresses.

T.3.6.1.3 NUHOMS®-61BTH 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 T.3.4. The side drop loads are Level D loads and are addressed in Section T.3.7. Conservative 2g axial, transverse and vertical loads have been used to envelope the normal horizontal dead weight, handling/transfer loads and seismic loads as described in Section T.3.6.1.3.2.

T.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 SHELL43 elements. The basket and rail model dimensions are based on drawings in Section T.1.5. The overall finite element model of the basket, rails and canister is shown in Figure T.3.6-1 for the Type 1 Basket and Figure T.3.6-2 for the Type 2 Basket. 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 the basket rails along the entire length during a side drop, only a 3" long slice of the basket, basket rails 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 basket rails are included in the model and are shown individually in Figure T.3.6-3 through Figure T.3.6-6. 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 TC Support Rails (Figure T.3.6-7, 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 them to the 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 Figure T.3.6-8 and Figure T.3.6-9. The finite element model of the canister and gaps is shown in Figure T.3.6-10 and Figure T.3.6-11.

Impact On TC Support Rails (Figure T.3.6-7, 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 or aluminum 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 and canister for both types of DSC are constructed from SA-240, 304 stainless steel. The basket rails of the Type 1 DSC are also constructed from same material. For the Type 2 DSC, the basket modification incorporates solid aluminum rails at 0°, 90°, 180°, and 270° azimuth orientations and aluminum plates that wrap the welded stainless steel rails at the 45°, 135°, 225°, and 315° azimuth orientations. The material for the solid aluminum rails for the Type 2 basket is based on Type 6061-O (annealed aluminum). 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:

Material Property	SA-240, 304 Stainless Steel at 500°F	6061-O Aluminum (Annealed) at 500°F
Modulus of Elasticity, E (psi)	25.8×10^6	7.9×10^6
Yield Strength (psi)	19,400	5,500
Tangent Modulus, E_t (psi)	5% of $E = 1.29 \times 10^6$	1% of $E = 7.9 \times 10^4$

The material properties used in the analysis are at 500°F. However, the resulting stresses are compared with the allowables at 750°F. This combination is considered conservative because using lower values of E, S_y and E_t (at 750°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 Figure T.3.6-8 and Figure T.3.6-9. Actual gap sizes at each rail nodal location are computed using an ANSYS macro. The gap element spring constant value of 0.5 x 10^6 lb/in. is used. 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, a small area and zero density (to zero their inertial loading contribution to the structure) were used in the analyses.

T.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 TC (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 TC	Horizontal	A	DW + 1g Axial	
		A	DW + 1g Trans.	
		A	DW + 1g Vert.	
		A/B	DW + 0.5g Axial+ 0.5 Trans.+ 0.5 Vert.	
Thermal(1),(2)	Horizontal	A/B	Bounding Thermal Stress	Bounding Thermal Stress
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 60g End Drop
End Drop(3)	Vertical	D	60g End Drop	60g End Drop

(1) The envelope of all storage and transfer thermal conditions is used for the horizontal load combinations, as applicable.
(2) The thermal stresses of the basket are addressed in Section T.3.4.
(3) Level D loads are addressed in Section T.3.7.

B. Operation/Storage Loads

The basket loads in the Horizontal Storage Module (HSM or HSM-H) 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/HSM-H (Operation/Storage Loads)

Loading	Basket Orientation	Service Level	Load	Enveloped Load for Analysis
Dead Weight	Horizontal	A/B	1g Down	1g Down
Seismic Loads (HSM)	Horizontal	C	0.37g Axial + 0.37g Trans. + 0.17g Vertical	2g Axial + 2g Trans. + 2g Vertical
Seismic Loads (HSM-H)	Horizontal	C	0.36g Axial + 0.41g Trans. + 0.20g Vertical	2g Axial + 2g Trans. + 2g Vertical
Thermal(1)	Horizontal	A/B	Bounding Thermal Stress	Bounding Thermal Stress

(1) The thermal stresses of the basket are addressed in Section T.3.4. The envelope of all storage thermal conditions and transfer thermal conditions (excluding vacuum drying) is used for all load combinations (as applicable).

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

A. Vertical Dead Weight (Basket in Vertical Orientation)

During 1g down loading, the fuel assemblies and fuel compartment are forced against the bottom of the cask. It is important to note that, for any longitudinal or near longitudinal loading, the fuel assemblies react directly against the end of the canister/cask and not through the basket structure as in lateral loading. It is only the weight of the basket and holddown ring (or top grid) that causes axial compressive stress during longitudinal loading. Axial compressive stresses are computed as if only the compartment tubes and outer box will withstand all the weight. A Type 1 basket weight of 23.5 kips (actual weight is 23.44 kips) and 28.0 kips (actual weight is 27.79 kips) for the Type 2 basket weight is used in the stress calculations.

Compressive Stress at Fuel Compartment Tubes and Outer Wrappers

Type 1:
Total weight = 23.5 kips

Weight excluding top grid, poison plates, aluminum plates, and rails,
23.5 – 1.55 – 3.17 – 0.88 – 3.68 – 1.98 = 12.24 kips
Section area = 12,240 /(164 x 0.284) = 262.80 in^2
Stress due to 1g = -23.5 / 262.80 = - 0.089 ksi

Type 2:
Total weight = 28.0 kips

Weight excluding top grid, poison plates, aluminum plates, and rails,
28.0 – 1.55 – 3.17 – 6.29 – 3.68 – 0.92 =12.39 kips

Section area = 12,390 /(164 x 0.284) = 266.02 in^2
Stress due to 1g = -28.0 / 266.02 = - 0.105 ksi

Shear Stress in Plate Insert Weld

64 Inserts support the poison plate weight (3.17 kips) for the limiting Type 1 basket

Load/insert = 3.17 / 64 = 0.050 kips
Weld Shear Area = 0.707 x 3 x 0.125 = 0.2652 in^2
Shear stress (1g) = 0.050 / 0.2652 = 0.19 ksi

Shear Stress in Rail Stud

During the 1g end loading, the rail will support its own weight. However, the analysis conservatively assumes that the weight of the stainless steel portion of the rail will be supported by the rail studs attached to the compartment outer boxes. The aluminum plates are slotted to allow for thermal expansion and will not load the studs.

Type 1-R45 (168 studs):
Weight of SST portion of rails = 3.68 kips
Weld Shear Area = $\pi/4\ (0.5^2 - 0.3^2) = 0.126\ in^2$
Shear stress (1g) = 3.68 / (0.126 × 168) = 0.17 ksi

Type 1-R90 (56 studs):
Weight of SST portion of rails = 1.98 kips
Weld Shear Area = $\pi/4\ (0.5^2 - 0.3^2) = 0.126\ in^2$
Shear stress (1g) = 1.98 / (0.126 × 56) = 0.28 ksi

Type 2-R45 (168 studs):
Weight of SST portion of rails = 3.68 kips
Weld Shear Area = $\pi/4\ (0.5^2 - 0.3^2) = 0.126\ in^2$
Shear stress (1g) = 3.68 / (0.126 × 168) = 0.17 ksi

Type 2-R90 (56 studs):
Weight of SST portion of rails = 0.92 kips
Weld Shear Area = $\pi/4\ (0.5^2 - 0.3^2) = 0.126\ in^2$
Shear stress (1g) = 0.92 / (0.126 × 56) = 0.13 ksi

Compressive Stress at Type 1 or Type 2 SST Rails and Aluminum Rails

The SST rails and aluminum rails are self-supporting in the vertical axial direction so that only self-weight induces compressive stresses. The holddown ring or top grid is assumed to be supported by the basket.

SST Rails:
Steel density = 0.284 lb/in^3
Length = 164 inches
Compressive stress (1g) = 0.284 (164) = 46.6 psi = 0.05 ksi

Aluminum Rails:
Aluminum density = 0.098 lb/in^3
Length = 164 inches
Compressive stress (1g) = 0.098 (164) = 16.1 psi = 0.02 ksi

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

The basket finite element model described in Section T.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 T.3.6-7). 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° and 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.

Axial Acceleration = 2g × 164/3 = 109.3g

To simulate the axial stress due to the axial acceleration, only one end of the basket model 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 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 to ANSYS result files. Maximum nodal stress intensities in the basket, rails and canister are shown in Figure T.3.6-12 through Figure T.3.6-23 and summarized in the following table. For the Type 2 basket, the aluminum of the R45 rails was not explicitly modeled. A check of reaction loads indicated that this amounts to approximately 5.3% of the total basket weight. Therefore, stress results were conservatively factored by 1.08 to account for the unmodeled aluminum.

Stress Summary of the Basket Due to Handling/Transfer Loads[1]
(2g Axial + 2g Transverse + 2g Vertical)

TYPE 1 BASKET

Component	Stress Classification	Stress (ksi)	Reference Figure
Basket	P_m	3.21	Figure T.3.6-12
	$P_m + P_b$	18.62	Figure T.3.6-13
Rail	P_m	2.66	Figure T.3.6-14
	$P_m + P_b$	11.93	Figure T.3.6-15
Canister	P_m	0.61	Figure T.3.6-16
	$P_m + P_b$	7.72	Figure T.3.6-17

TYPE 2 BASKET

Component	Stress Classification	Stress[2] (ksi)	Reference Figure
Basket	P_m	4.11	Figure T.3.6-18
	$P_m + P_b$	18.56	Figure T.3.6-19
Rail	P_m	3.29	Figure T.3.6-20
	$P_m + P_b$	20.77	Figure T.3.6-21
Canister	P_m	1.00	Figure T.3.6-22
	$P_m + P_b$	11.74	Figure T.3.6-23

(1) For this load case the DSC is on the cask rails at 18.5° with vertical inside the cask.

(2) ANSYS plot results are conservatively scaled by 1.08 to account for unmodeled aluminum at the Type 2 basket R45 rails.

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 presented in Section T.3.7.4.3.

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

Loading	Component	Service Level	Stress Class.	Loads	Type 1 Stress (ksi)	Type 2(1) Stress (ksi)	Allow.(2,3,4) Stress (ksi)
Vertical Dead Weight	Basket	A	P_m	1g Axial	0.09	0.11	15.60
		A	$P_m + P_b$	1g Axial	0.09	0.11	23.40
		A/B	$P_m + P_b + Q$	1g Axial + Therm.	30.82	30.84	46.80
	Plate Insert	A	P_{Shear}	1g Axial	0.19	0.19	8.19
		A/B	$P_{Shear} + Q_{Shear}$	1g Axial + Therm.	1.32	1.32	16.38
	Rail Studs	A	P_{Shear}	1g Axial	0.28	0.17	12.87
	SST Rails	A	P_m	1g Axial	0.05	0.05	15.60
		A	$P_m + P_b$	1g Axial	0.05	0.05	23.40
		A/B	$P_m + P_b + Q$	1g Axial + Therm.	8.93	8.93	46.80
	Alum. R90 Rails	A	Bearing	1g Axial	---	0.02	6.00
Horiz. Dead Weight	All Basket Components	A	P_m	1g Axial	Enveloped by Handling		
		A	$P_m + P_b$	1g Axial			
		A/B	$P_m + P_b + Q$	1g Axial + Therm.			
Handling	Basket	A	P_m	2g Axial,Vert.,Trans	3.21	4.17	15.60
		A	$P_m + P_b$	2g Axial,Vert.,Trans	18.63	18.61	23.40
		A/B	$P_m + P_b + Q$	2g Axial,Vert.,Trans + Thermal	38.84	38.82	46.80
	Plate Insert	A	P_{Shear}	2g Axial	0.38	0.38	8.19
		A/B	$P_{Shear} + Q_{Shear}$	2g Axial + Therm.	1.65	1.65	16.38
	Rail Studs	A	P_{Shear}	2g Axial	5.44	5.44	12.87
	SST Rails(7)	A	P_m	2g Axial,Vert.,Trans	2.66	3.30	15.60
		A	$P_m + P_b$	2g Axial,Vert.,Trans	11.94	20.82	23.40
		A/B	$P_m + P_b + Q$	2g Axial,Vert.,Trans + Thermal	13.34	22.22	46.80
	Alum. R90 Rails	A	Bearing	2g Axial,Vert.,Trans	---	0.133	4.85

Notes:

1. ANSYS plot results for inertia loads scaled by 1.08 to account for unmodeled aluminum at the Type 2 basket R45 rails.
2. $P_m \le S_m$; $P_m + P_b \le 1.5\ S_m$; $P_m + P_b + Q \le 3\ S_m$ at 750°F for SST components.
3. Bearing $\le S_Y$ for Alum. R90 rail at 450°F during vacuum drying, 550°F for handling,
4. For plate insert weld shear stresses, $P_{Shear} \le 0.35\ (1.5\ S_m)$; $P_{Shear} + Q_{Shear} \le 0.35\ (3\ S_m)$ at 750°F. For stud weld shear stresses, $P_{Shear} \le 0.55\ (1.5\ S_m)$ at 750°F.
5. Not Used
6. Not Used
7. The relatively high $P_m + P_b$ stresses are local stresses on the cross-section but occur along the entire length of the rail. A portion of this local stress is actually a secondary stress due to conservative, forced displacement compatibility between the basket and the basket rails. Stresses are much lower away from the locally higher stresses.

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

A. Horizontal Dead Weight

The 1g down loading is enveloped by a conservative acceleration load as described below in paragraph B.

B. Seismic Loads

Finite Element Model Analysis of the Basket Due to Seismic Load

The basket finite element model described in Section T.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 seismic loads are conservatively enveloped by a combined loading of 2g axial + 2 g transverse + 2g vertical.

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. In addition, a factor of 2 is applied to correct for the fact that the basket model has only one element in the axial direction.

Axial Acceleration = 2x2g × 164/3 = 218.6g

To simulate the axial stress due to the axial acceleration, only one end of the basket model 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 Figure T.3.6-24 through Figure T.3.6-35 and summarized in the following table.

Summary of the Basket Stresses due to Seismic Load(1)
(2g Axial + 2g Transverse + 2g Vertical)

(TYPE 1 DSC)

Component	Stress Classification	Stress (ksi)	Reference Figure
Basket	P_m	3.00	Figure T.3.6-24
	$P_m + P_b$	19.68	Figure T.3.6-25
Rail	P_m	2.66	Figure T.3.6-26
	$P_m + P_b$	15.23	Figure T.3.6-27

(TYPE 2 DSC)(2)

Component	Stress Classification	Stress (ksi)	Reference Figure
Basket	P_m	6.22	Figure T.3.6-30
	$P_m + P_b$	26.88	Figure T.3.6-31
Rail	P_m	3.90	Figure T.3.6-32
	$P_m + P_b$	24.97	Figure T.3.6-33

(1) For this load case the DSC is on the rails at 30° with vertical inside the HSM or HSM-H.

(2) ANSYS plot results are scaled by 1.08 to conservatively account for unmodeled aluminum at the Type 2 R45 rails.

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

Discussion

The basket will be subjected to acceleration of 0.37g in the axial direction, 0.37g in the transverse direction, and 0.17g in the vertical direction during a seismic event in the HSM. Similarly, in the HSM-H, the basket seismic accelerations are 0.36g in the axial direction, 0.41g in the transverse direction, and 0.2g in the vertical direction. 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 for a bounding acceleration of 2g in the axial direction, 2g in the transverse direction and 2g in the vertical direction.

Analysis

The limiting case for shear stress in the rail stud (and rail stud weld) is consideration of a 2g axial load where the bottom 3 rails are not allowed to slide against the surface of the canister. At the same time, the fuel is not allowed to slide inside the basket. This results in a potential load on the rail studs at the lower 3 basket rails. The total axial load applied to the basket is limited by the static coefficient of friction, f_{static}. As soon as the applied load exceeds the reaction due to static friction, the basket slides in the canister and the load is reduced to a value consistent with the sliding coefficient of friction, $f_{sliding}$.(which is less than the static coefficient of friction). This potential load on the rail studs, F_{stud}, is reduced by the friction load between the basket fuel compartments and the basket rails (conservatively assume sliding friction). Using an upper bound for the static coefficient of friction, a lower bound for the sliding coefficient of friction, and the heaviest basket (Type 2), the rail stud load is conservatively calculated as follows:

$$F_{applied} = f_{static} (W_{basket} + W_{fuel})$$

$$F_{stud} = F_{applied} - f_{sliding} (W_{basket} + W_{fuel} - W_{3rails})$$

$$= f_{static} (W_{basket} + W_{fuel}) - f_{sliding} (W_{basket} + W_{fuel} - W_{3rails})$$

$$= (f_{static} - f_{sliding})(W_{basket} + W_{fuel}) + f_{sliding} W_{3rails}$$

An upper bound on f_{static} is 0.80 and a lower bound on $f_{sliding}$ is 0.25. The force "$F_{applied}$" is computed conservatively, ignoring any uplift due to vertical seismic acceleration.

Substituting the above bounding friction coefficients, and the weights (use a conservative Type 2 basket weight of 28,000 lbs), gives the following:

$$F_{stud} = (0.80 - 0.25) (28{,}000 + 43{,}005) + 0.25 (2{,}800) \quad \text{(Conservative)}$$

$$= 39{,}752 \text{ lbs}$$

Only the studs in the bottom three rails (8 x 7 = 56 studs) take this axial load. The stress area in the rail stud welds, A, is:

$$A = 56 (\pi / 4) (0.50^2 - 0.30^2) = 7.037 \text{ in}^2$$

Therefore, the shear stress in the stud welds is:

$$\tau = F_{stud} / A = 39{,}752 / 7.307 = 5{,}440 \text{ psi}$$

D. Modal Analysis of the Basket

For 61BTH Type 1 basket results and conclusion are the same as reported in Section K.3.6.1.3.4.

The 61BTH Type 2 design differs only slightly from the 61BTH Type 1 design at the basket rails resulting in a slightly heavier basket. However, the increased weight would not be enough to reduce the frequency from 125 Hz to 33 Hz. Therefore, similar to the Type 1 Basket the seismic accelerations will not be amplified.

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 750°F. For conservatism, allowables are taken at a temperature of 750° F.

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

Loading	Component[5]	Service Level	Stress Class.	Loads	Type 1 Stress (ksi)	Type 2[1] Stress (ksi)	Allow.[2,3] Stress (ksi)
Horiz. Dead Weight	Basket	A	P_m	1g Vert.	0.61	2.19	15.60
		A	$P_m + P_b$	1g Vert.	2.72	7.82	23.40
		A/B	$P_m + P_b + Q$	1g Vert. + Therm.	22.93	28.03	46.80
	SST Rails	A	P_m	1g Vert.	1.20	1.37	15.60
		A	$P_m + P_b$	1g Vert.	7.38	10.43	23.40
		A/B	$P_m + P_b + Q$	1g Vert. + Therm.	8.78	11.83	46.80
	Alum R90 Rails	A	Bearing	1g Vert.	---	0.045	4.85
Seismic	Basket	C	P_m	2g Axial, Vert., Trans	3.00	6.22	23.40
		C	$P_m + P_b$	2g Axial, Vert., Trans	19.68	26.88	35.10
	SST Rails[7]	C	P_m	2g Axial, Vert., Trans	2.66	3.90	23.40
		C	$P_m + P_b$	2g Axial, Vert., Trans	15.23	24.97	35.10
	Alum R90 Rails	C	Bearing	2g Axial, Vert., Trans	---	0.133	4.85

Notes:

1. ANSYS plot results for inertia loads scaled by 1.08.
2. Level A/B: $P_m \leq S_m$; $P_m + P_b \leq 1.5\ S_m$; $P_m + P_b + Q \leq 3\ S_m$ at 750°F for SST components. Level C: $P_m \leq 1.5\ S_m$; $P_m + P_b \leq 2.25\ S_m$ at 750°F for SST components.
3. Bearing < S_Y for Alum. R90 rail at 550°F for storage (conservative).
4. These results are reported in Table T.3.7-12 for the Type 1 DSC and Table T.3.7-13 for the Type 2 DSC.
5. Insert plate weld and rail stud and stud weld shear stresses are enveloped by the evaluation performed for the transfer conditions (same loads, lower allowables).
6. Not Used
7. The relatively high $P_m + P_b$ stresses are local stresses on the cross-section but occur along the entire length of the rail. A portion of this local stress is actually a secondary stress due to conservative, forced displacement compatibility between the basket and the basket rails. Stresses are much lower away from the locally higher stresses.

T.3.6.1.4 DSC Support Structure Analysis

The DSC support structure inside the HSM is qualified for a maximum DSC weight of 102 kips in Appendix M. The maximum DSC weight is 93 kips for the 61BTH. Therefore, the support structure analysis results presented in Appendix M bounds these results for 61BTH Type 1 and Type 2 DSC.

The HSM-H support structure is analyzed conservatively for 110 kips DSC weight in Appendix P. Therefore, results presented in Appendix P are applicable when the HSM-H support structure is loaded with a 61BTH DSC.

T.3.6.1.5 HSM and HSM-H Design Analysis

The HSM and HSM-H are qualified for a maximum DSC weight of 102 kips in Appendix M and 110 kips in Appendix P, respectively. Therefore, the HSM and HSM-H (loaded with the 61BTH Type 1 and the Type 2 DSC) results are bounded by the results presented in Appendix M and Appendix P.

The HSM Models 80/102/152/202 are qualified for a maximum heat load of 24 kW in Section 8.0 (for HSM Models 80/102) or the applicable appendix (for HSM Models 152/202) which bounds the maximum heat load up to 22 kW for the Type 1 DSC. The HSM-H is qualified for maximum heat load up to 40.8 kW which bounds the results of up to 31.2 kW for the 61BTH Type 1 and the Type 2 DSC.

T.3.6.1.6 HSM and HSM-H Door Analyses

HSM Door Analysis

No change.

HSM-H Standard Door Analysis

To accommodate the length of 61BTH DSC, the concrete thickness of the HSM-H door is reduced by 4". The evaluation presented in Appendix P does not take credit for the concrete portion of the door. Thus, the Appendix P evaluation remains unchanged.

HSM-H Optional Door Analysis

The optional shield door for the HSM-H consists of 3" square or round thick steel plate attached to the front wall concrete by four 1" bolts for square plate or four clamps for round plate. At the rear of the 3" thick steel plate, a stepped circular reinforced concrete block is provided.

The optional door is conservatively evaluated for a bounding pressure of 10 psi to bound normal condition loading. Due to this pressure, the maximum moment and shear in the door are equal to 29.2 kip-in/ft and 2.1 kips/ft, respectively. The allowable bending moment and shear forces in the door (without taking credit for the concrete) are 486 kip-in/ft and 518 kips/ft, respectively. Therefore, the door is qualified to meet the design requirements of the code.

T.3.6.1.7 HSM and HSM-H Heat Shield Analysis

No change.

T.3.6.1.8 HSM Axial Retainer for DSC

The HSM axial retainer is qualified for a maximum DSC weight of 102 kips in Appendix M. The maximum DSC weight is 93 kips for the 61BTH Type 2 DSC. Therefore, the axial retainer results presented in Appendix M bounds these results for 61BTH Type 1 and Type 2 DSC.

The HSM-H axial retainer is qualified conservatively for 110 kips DSC weight in Appendix P. Therefore, results presented in Appendix P are applicable to 61BTH without any change.

T.3.6.1.9 OS197/OS197H/OS197FC-B On-site TC Analysis

This section documents the stress analysis performed for the OS197/OS197H/OS197FC-B TC. The OS197FC described in Appendix P is modified to allow radial distribution of the cooling air flow as it enters the ram access opening at the bottom of the cask (since the length of the 61BTH DSC is approximately equal to the length of the cask cavity, the cask spacer used to distribute the incoming air in the OS197FC can not be used in the OS197FC-B). Thus, radial wedge-shaped ½" plates are placed on the inside of the cask bottom to create channels that distribute the air radially to the annulus between the cask and the DSC. To maintain the cask cavity length unchanged the inside of the top lid is inset by the same amount. To maintain the lid thickness unchanged, ½" steel material is added to the outside of the top lid. All other lid details including the lid vents remain unchanged as in the OS197FC. The modified OS197FC is referred as the OS197FC-B.

Modified Lid Evaluation

This section addresses the evaluation of the OS197FC-B top lid. Since the total lid thickness of the OS197FC-B remains the same and the geometry of the vent cutouts are not changed relative to the OS197FC in Appendix P, the evaluation of the top lid presented in Appendix P for the OS197FC is applicable.

Thermal Stress Evaluation

This section also addresses the changes in cask maximum temperatures and temperature distribution profiles that result from the 61BTH DSC relative to those documented for the 24PTH in Appendix P. This thermal stress evaluation is applicable to the OS197/OS197H/OS197FC-B TCs.

The thermal analyses of the TC presented in Chapter T.4.5 provide the temperature and temperature distributions for the various ambient/operational conditions of transfer. For purposes of the thermal stress analysis, the TC is evaluated for the bounding temperature distributions resulting from transfer of a 61BTH DSC with heat loads of up to 31.2 kW with and without air circulation.

Comparison of the cask temperature profiles obtained from the thermal analysis of the OS197FC-B with a 61BTH with those in Appendix P show that the Appendix P results are bounding, as shown in the following table:

TC Cask Component	Maximum Temperature (°F)		
	24PTH DSC	61BTH DSC	
		No Air	Air Circulation
Top Forging	297	217	231
Inner Liner	384	302	285
Bottom Forging	259	257	210
Structural Shell	329	257	241
NS-3 Cover Plate	217	216	174
Ram Access Forging	201	236	169
Bottom End Cover Plate	227	240	189
Top Lid	273	193	217
Lead (Shielding)	379	298	281

The table above shows that the maximum temperatures in the TC components, documented in Appendix P (OS197FC loaded with a 24PTH), bound those of the OS197FC-B loaded with a 61BTH DSC, with the exception of the bottom cover plate and ram access forging. Thermal stress analysis results of the TC with the 61BTH temperature distributions shown in Table T.3.6-8 confirm that the Appendix P stress analysis results are bounding for all TC components except the top and bottom lids. Thus, results for only these two TC components are reported in Table T.3.6-9.

Payload Lift Evaluation

The evaluations for the OS197 and OS197H TCs are based on DSC maximum allowable wet payload weight of 102,410 lbs and 126,000 lbs, and maximum allowable DSC dry payload weights of 97,250 lbs and 116,000 lbs, respectively. The maximum total cask payload with a dry-loaded NUHOMS®-61BTH DSC is approximately 93,120 lbs and wet-loaded 61BTH DSC is approximately 96,300 lbs. Therefore, an OS197FC-B TC that is based on either the OS197 or the OS197H TC is acceptable with any NUHOMS®-61BTH DSC as long as the total TC dry and wet payload weights are within their respective analyzed weights listed above.

T.3.6.2 Off-Normal Load Structural Analysis

Table T.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 or HSM-H and the extreme ambient temperatures of -40°F (winter) and +117°F (summer). These events envelope the range of expected off-normal structural loads and temperatures acting on the DSC, transfer cask, and HSM-H. These off-normal events are described in Section 8.1.2 and Section T.4.

T.3.6.2.1 Jammed DSC During Transfer

The interfacing dimensions of the top end of the transfer cask and the HSM or HSM-H 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 or HSM-H, the DSC binds or becomes jammed during transfer operations.

The interfacing dimensions and design features of the HSM Models 80, 102, 152, 202 or HSM-H access opening, DSC Support Structure and the OS197 OS197H/OS197FC-B transfer remain unchanged from those described in Section 8.1.2 or the applicable appendix in the UFSAR. The insertion and extraction forces applied on the NUHOMS®-61BTH during loading and unloading operations are the same as those specified for the NUHOMS®-52B system. The discussion in Section 8.1.2.1(B) applies to the 61BTH DSC. However the NUHOMS®-61BTH DSC shell thickness is 0.5 inches (compared to 0.625 inches for the NUHOMS®-52B DSC shell) and the outside radius is 33.625 inches. Hence, the NUHOMS®-61BTH DSC shell stresses, based on a force of 80 kips, and a moment arm of 33.625 inches are calculated below.

Axial Sticking of the DSC

$$S_{mx} = \frac{M}{S}$$ (From Equation 8.1-9, Section 8.1.2.1)

Where:

M = 80 x 33.625 = 2690 in.-kip, Bending moment

S = 1734 in.^{3}, DSC section modulus

Therefore:

S_{mx} = 1.55 ksi

This magnitude of stress is negligible when compared to the allowable membrane stress of 17.2 ksi and is bounded by stresses for other handling loads as shown in Table T.3.6-4.

Binding of the DSC

As discussed in Section 8.1.2.1 (C), if axial alignment within system operating specifications is not achieved, it may be possible to pinch the DSC shell as shown in Figure 8.1-32. From Section 8.1.2.1 (C), the pinching force is taken as the product of the maximum ram loading of 80,000 pounds and the sine of a 1 degree angle, or 1,400 pounds.

The 1,400 pound load is conservatively assumed to be applied as a point load at a location away from the ends of the TC or DSC. The resulting maximum stresses are given by Table 31, Case 9a of Roark [3.12] as:

Membrane stress:

$$\sigma = \frac{0.4P}{t^2}$$

Bending stress:

$$\sigma' = \frac{2.4P}{t^2}$$

Therefore, the maximum membrane plus bending stress is:

$$\sigma + \sigma' = \frac{2.8P}{t^2}$$

For the DSC shell, t=0.500 inch. Substituting for t and using a value of P equal to 1,400 pounds, the maximum extreme fiber stresses in the DSC shell are 15.7 ksi. This local stress is conservative in that small deformations create a larger contact area, i.e., not a point load, and the stress is actually lower than calculated. In addition, the deformations are limited by the gap between the shell and basket. As such, this stress is considered a secondary stress and is enveloped by the handling stresses shown in Table T.3.6-4.

The tangential component of ram loading under the assumed condition is less than the 80,000 lbs force of the jammed condition, axial sticking calculated above and as such is not considered further.

In both scenarios for a jammed DSC, the stress in the DSC shell is demonstrated to be much less than the ASME Code allowable stress and below the yield value of the material. Therefore, permanent deformation of the DSC shell does not occur. There is no potential for release of radioactive material.

There is no change to the required corrective actions, as described in the UFSAR Section 8.1.2, for the jammed DSC conditions.

T.3.6.2.2 Off-Normal Thermal Loads Analysis

As described in 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 117°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 or HSM-H during storage of a DSC.

Chapter T.4 provides the off-normal thermal analyses for storage and transfer mode for the NUHOMS®-61BTH DSC. The resulting stress intensities for the NUHOMS®-61BTH are acceptable.

T.3.6.2.3 Damaged Fuel Integrity Assessment for Off-Normal Loads

The evaluation of the damaged fuel for off-normal loads is discussed in Section T.3.6.3.

T.3.6.3 Damaged Fuel Cladding Structural Evaluation

Proprietary Information withheld under 10 CFR 2.390

Proprietary Information withheld under 10 CFR 2.390

T.3.6.3.1 Stress Evaluation of the Damaged Fuel Cladding

A. Design Input / Data

Proprietary Information withheld under 10 CFR 2.390

B. Loads

Proprietary Information withheld under 10 CFR 2.390

- Dead Weight

Proprietary Information withheld under 10 CFR 2.390

Proprietary Information withheld from pages T.3.6-23 through T.3.6-33 under 10 CFR 2.390

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

Load Type	Affected Component				
	DSC Shell Assembly	**DSC Basket**	**DSC Support Structure**	**Reinforced Concrete HSM/HSM-H**	**On-site TC**
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 T.3.6-2
NUHOMS® Off-Normal Operating Loading Identification

Load Type	Affected Component				
	DSC Shell Assembly	**DSC Basket**	**DSC Support Structure**	**Reinforced Concrete HSM/HSM-H**	**On-site TC**
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 T.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 SA-240 Type 304	-100	--	--	--	29.1	--
	-20	20.0	30.0	75.0	--	--
	70	-	--	--	28.3	--
	100	20.0	30.0	75.0	--	8.6
	200	20.0	25.0	71.0	27.6	8.9
	400	18.7	20.7	64.0	26.5	9.5
	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
	750	15.6	17.2	63.3	24.5	10.0
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 T.3.6-4
Maximum NUHOMS®-61BTH DSC Stresses for Normal and Off-Normal Loads
(Type 1 DSC)

DSC Components	Stress Type	Maximum Stress Intensity(ksi)[1,5]			
		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	20.74
Inner Top Cover Plate	Primary Membrane	0.72	1.80	N/A	2.28
	Membrane + Bending	2.12	8.58	N/A	2.56
	Primary + Secondary	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	1.26	10.54[8]	25.03	1.26
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	5.15
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	1.11	1.10[8]	28.11	23.06

(1) Values shown are maximum irrespective of location.
(2) Envelope of normal and off-normal ambient temperature conditions.
(3) Not used.
(4) Maximum of 1g vertical, 1g axial, 60 kips pull or 80 kips push. Maximum of 1g vertical, 1g transverse, and 1g axial envelops SRSS (0.5g vertical, 0.5g transverse, 0.5 axial).
(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.

Table T.3.6-5
Maximum NUHOMS®-61BTH DSC Stresses for Normal and Off-Normal Loads (Type 2 DSC)

DSC Components	Stress Type	Maximum Stress Intensity(ksi)(1,5)			
		Dead Weight	Internal Pressure(7)	Thermal(2)	Normal Handling(4)
DSC Shell	Primary Membrane	2.70	8.90	N/A	4.10
	Membrane + Bending	8.46	9.18	N/A	8.46
	Primary + Secondary	8.46	16.29	49.54	20.78
Inner Top Cover Plate	Primary Membrane	0.58	0.74	N/A	1.68
	Membrane + Bending	1.67	16.76	N/A	1.84
	Primary + Secondary	1.63	16.76	24.52	1.85
Outer Top Cover Plate	Primary Membrane	1.11	2.65	N/A	1.11
	Membrane + Bending	1.63	7.43	N/A	1.63
	Primary + Secondary	1.17	7.22	23.69	1.17
Inner Bottom Cover Plate	Primary Membrane	0.71	0.56(8)	N/A	3.22
	Membrane + Bending	0.84	1.48(8)	N/A	4.80
	Primary + Secondary	0.83	1.51(8)	36.41	4.83
Outer Bottom Cover Plate	Primary Membrane	0.74	0.83(8)	N/A	5.27
	Membrane + Bending	1.31	1.47(8)	N/A	22.72
	Primary + Secondary	1.18	1.15(8)	30.81	23.15

(1) Values shown are maximum irrespective of location.

(2) Envelope of Normal and Off-Normal ambient temperature conditions.

(3) Not used.

(4) Maximum of 1g vertical, 1g transverse, 1g axial, 60 kips pull or 80 kips push. Maximum of 1g vertical, 1g transverse, and 1g axial envelops SRSS (0.5g vertical, 0.5g transverse, 0.5g axial).

(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 15 psi internal pressure results are scaled to obtain stresses for the off-normal condition 20 psi internal pressure.

Table T.3.6-6
Design Parameters of 61BTH BWR Fuel Assemblies

Tube Arrays	7 x 7(1)	8 x 8(1)	8 x 8(1)	8 x 8(1)	8 x 8(1)	9 x 9(1)	10 x 10(1)	7 x 7(1)	7 x 7(1)	8 x 8(1)	8 x 8(1)	8 x 8(1)	9 x 9(1)	10 x 10(1)	8 x 8(1)	8 x 8(1)
GE Designation	GE1, GE2, GE3	GE4	GE5, GE-Pres, GE-Barrier, GE8, Type 1	GE8	GE9, GE10	GE11, GE13	GE12, GE14	ENC-IIIA	ENC-IIIE ENC-IIIF	ENC-Va ENC-Vb	FANP 8X8-2	FANP 9X9-2	Siemens, QFA	ATRIUM-10	XXX-RCN	STD GE-4
No. of Fuel Rods	49	63	62	60	60	66	78	49	48	60	62	79	72	83	59	63
Max. Active Fuel Length (in)	144	146	150	150	150	146	150	144	144	144	150	150	145.24	149.54	146	146
Fuel Tube OD (in)	0.563	0.493	0.483	0.483	0.483	0.44	0.404	0.570	0.570	0.5015	0.484	0.424	0.433	0.3957	0.493	0.493
Corroded Fuel Tube OD(2) (in)	0.5576	0.4876	0.4776	0.4776	0.4776	0.4346	0.3986	0.5646	0.5646	0.4961	0.4786	0.4186	0.4276	0.3903	0.4876	0.4876
Minimum Clad Thickness (in)	0.032	0.034	0.032	0.032	0.032	0.028	0.026	0.0355	0.0355	0.0360	0.0350	0.0300	0.0262	0.0239	0.034	0.034
Corroded Clad Thickness(2) (in)	0.0293	0.0313	0.0293	0.0293	0.0293	0.0253	0.0233	0.0328	0.0328	0.0333	0.0323	0.0273	0.0235	0.0212	0.0313	0.0313
Fuel Tube I.D. (in)	0.499	0.425	0.419	0.419	0.419	0.384	0.352	0.499	0.499	0.4295	0.4140	0.3640	0.3806	0.3479	0.425	0.425
Fuel Tube Radius Average (in)	0.2642	0.2282	0.2242	0.2242	0.2242	0.2047	0.1877	0.2659	0.2659	0.2314	0.2232	0.1957	0.2021	0.1846	0.2282	0.2282
Corroded Fuel Tube Area (in^2)	.0486	.0449	.0413	.0413	.0413	.0325	.0275	.0548	.0548	.0484	.0453	.0336	.0298	.0246	.0449	.0449
Corroded Fuel Tube M.I. (in^4)	.001702	.001173	.001041	.001041	.001041	.000684	.000486	.001945	.001945	.001303	.001133	.000645	.000611	.000420	.001173	.001173
Irradiated Yield Stress (psi)(3)	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712	73,712
Young's Modulus E, (psi)(3)	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07	1.48E+07

Notes:

(1) The maximum fuel assembly weight with channel = 705 lbs used.

(2) Includes 0.0027 in. reduction in cladding thickness to account for water side and inner side cladding oxidation.

(3) These values are taken from Reference [3.21].

Table T.3.6-7
Computed Maximum Fuel Rod Stresses and their Ratio to Yield Strength

Normal and Off-Normal Load Case	Computed Stress σ_{Max} (psi)				Ratio
	7x7 Fuel	8x8 Fuel	9x9 Fuel	10x10 Fuel	σ_{max}/σ_y (1)
1. On site transfer from fuel building to ISFSI	5,071	4,881	5,628	5,923	0.08
2. Hypothetical one foot end drop	9,040	8,540	9,850	10,370	0.14
3. Hypothetical one foot side drop	35,010	40,830	46,270	44,190	0.63

(1) σ_{max} = Maximum of 7x7, 8x8, 9x9 and 10x10 fuel rod cladding computed stresses.
σ_y = Yield stress of the Zircaloy cladding material equal to 73,700 psi [3.22].

Table T.3.6-8
OS197FC-B TC Enveloping Thermal Stresses

TC Component	Maximum Thermal Stress Intensity (ksi)
Top Forging	24.9
Inner Liner	39.8
Bottom Forging	40.3
Structural Shell	15.5
Ram Access Forging	17.1
Bottom End Cover Plate	12.6
Top Lid	26.8

Table T.3.6-9
OS197/OS197H/OS197FC-B TC Combined Stresses For Normal Condition Loads(1)(2)

TC Component	Stress Category	Maximum Primary Stress (ksi)	Thermal Stress (ksi)	Combined Stress (ksi)	Allowable Stress (ksi)	Stress Ratio (ksi)	Notes
Top Cover Plate (Type 304)	P_m	0.72	N/A	0.72	18.7	0.04	400°F
	$P_m + P_b$	5.44	N/A	5.44	28.1	0.19	
	$P_m + P_b + Q$	5.44	26.8	32.3	56.1	0.58	
Bottom Cover Plate (Type 304)	P_m	1.18	N/A	1.18	18.7	0.06	400°F
	$P_m + P_b$	8.57	N/A	8.57	28.1	0.30	
	$P_m + P_b + Q$	8.57	12.6	21.1	56.1	0.38	

Notes:
1. Primary stresses (mechanical load stresses) are based on the bounding OS197H TC stresses as summarized in Chapter 8.
2. Thermal stresses are applicable to the OS197/OS197H/OS197FC-B TCs for heat loads above 24 kW. For heat loads of up to 24 kW, the thermal stresses as reported in Chapter 8 are applicable.
3. Results for other TC components (Shell, Inner Liner, Top Flange, Bottom Support Ring) are not changed from those shown in Table P.3.6-13.

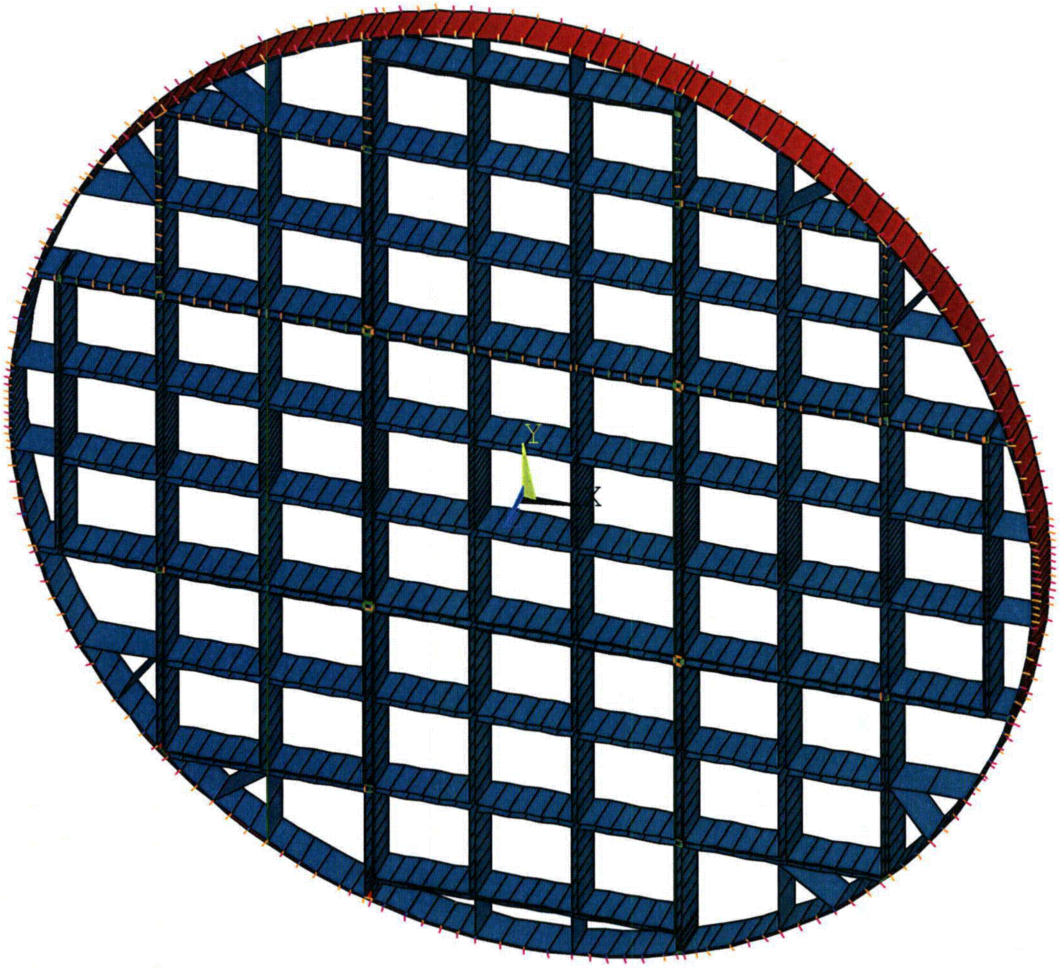


Figure T.3.6-1
Type 1 Finite Element Model – Full Basket Section

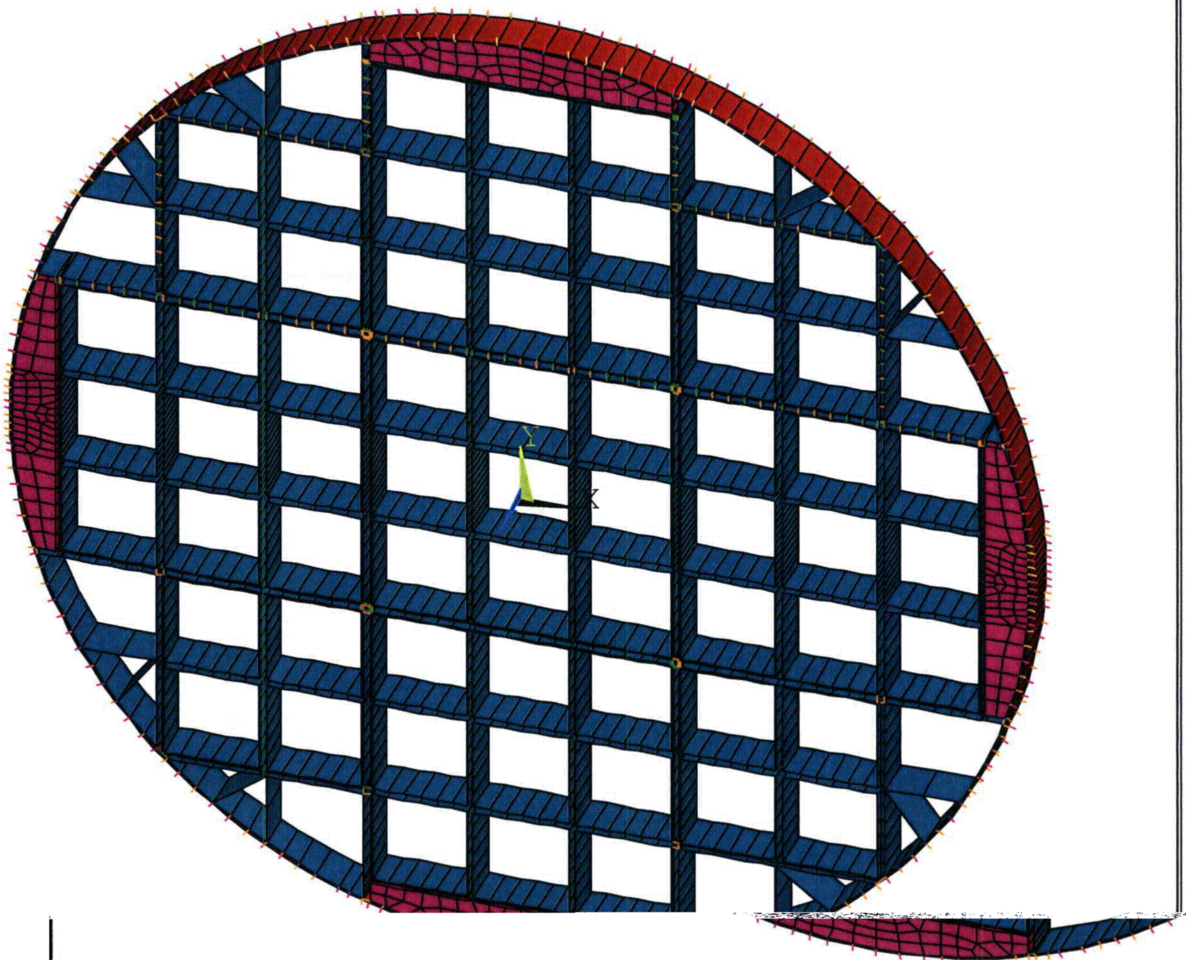


Figure T.3.6-2
Type 2 Finite Element Model – Full Basket Section

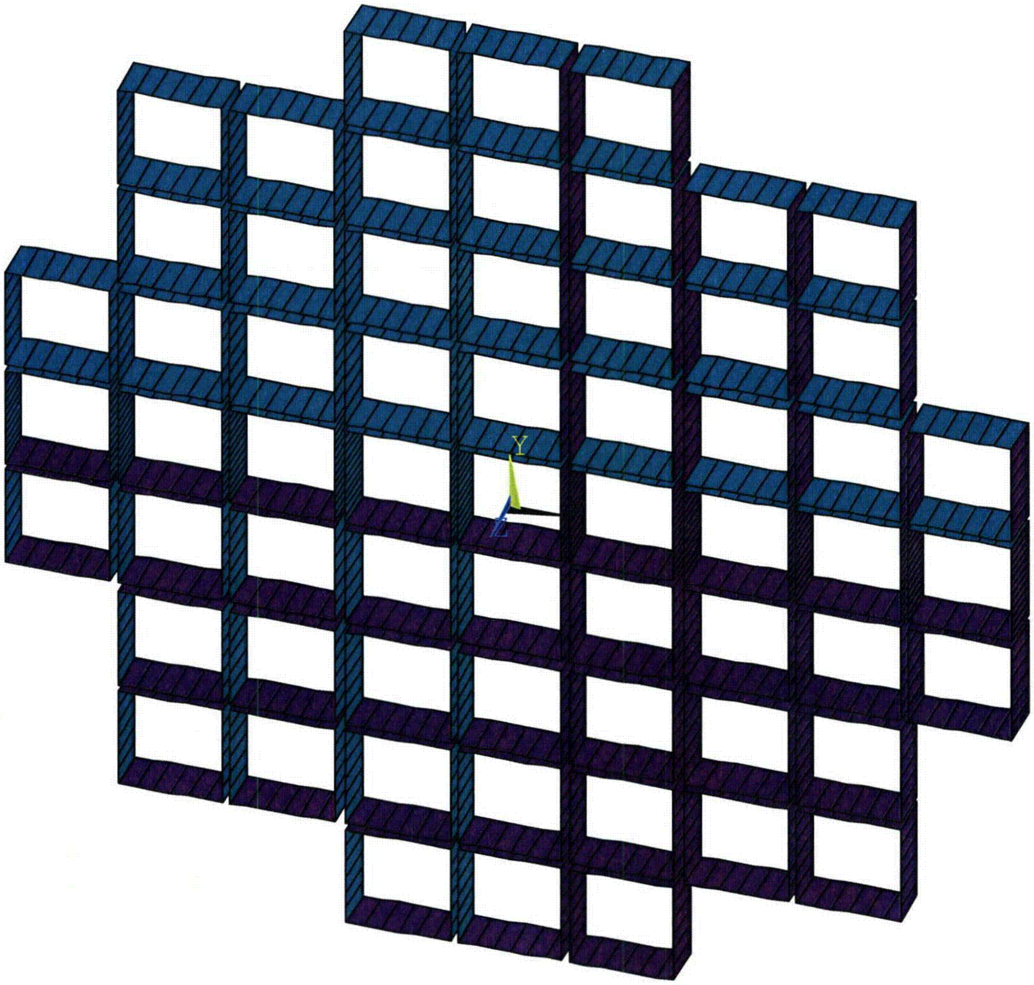


Figure T.3.6-3
Finite Element Model – Inner Boxes

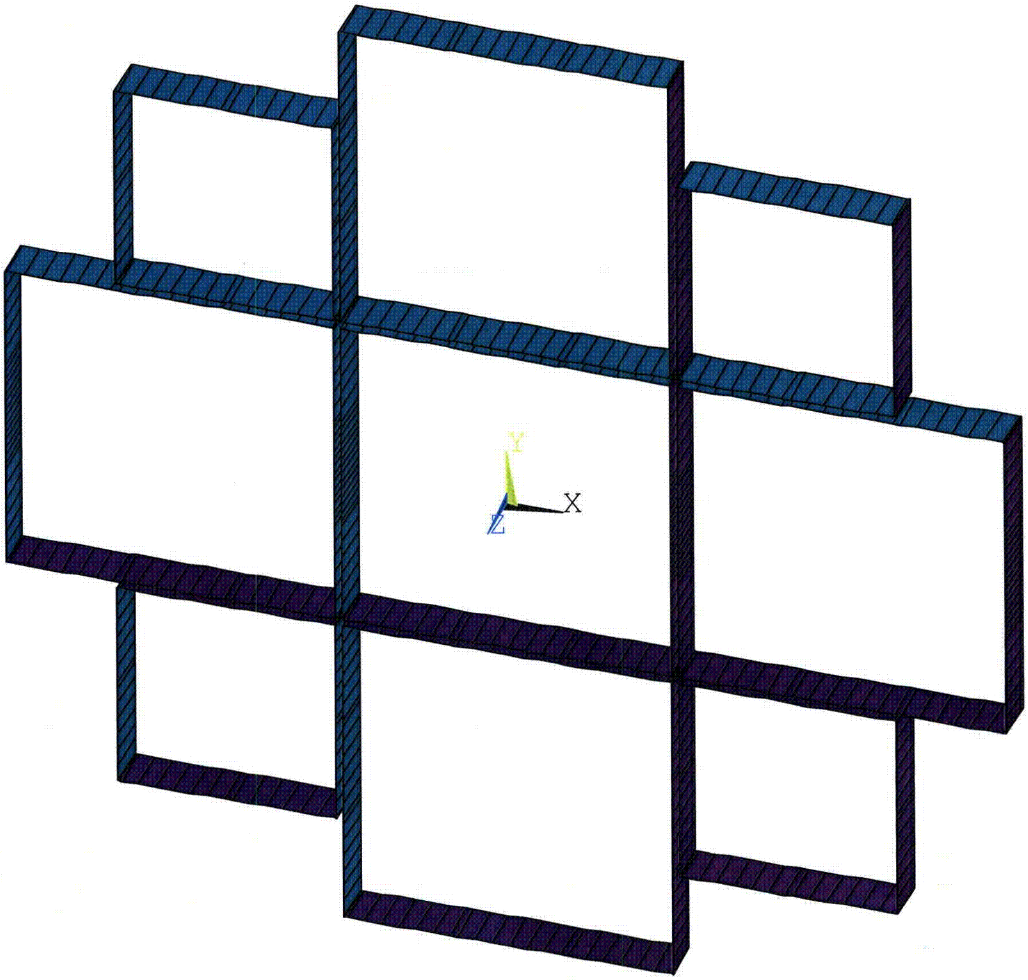


Figure T.3.6-4
Finite Element Model – Outer Boxes

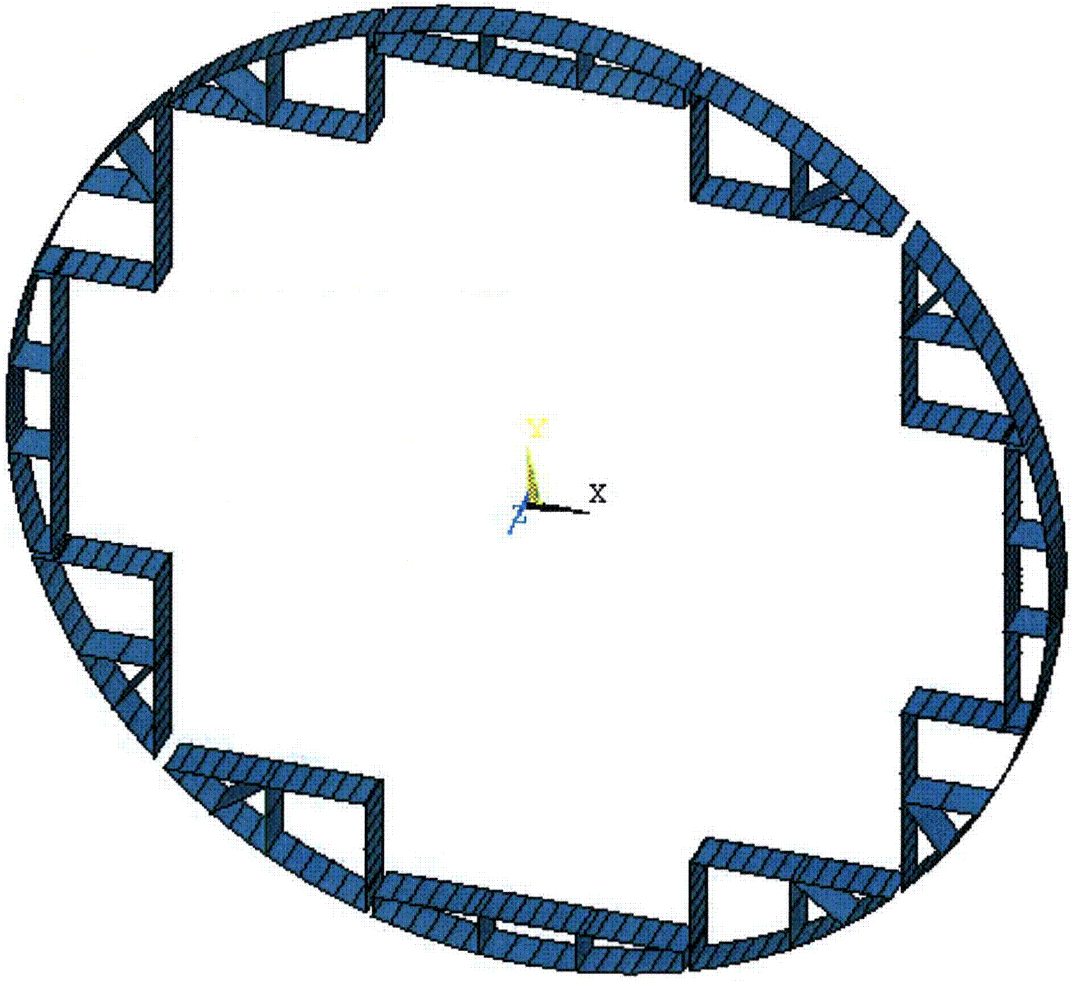


Figure T.3.6-5
Finite Element Model – Rails
(Type 1 Basket)

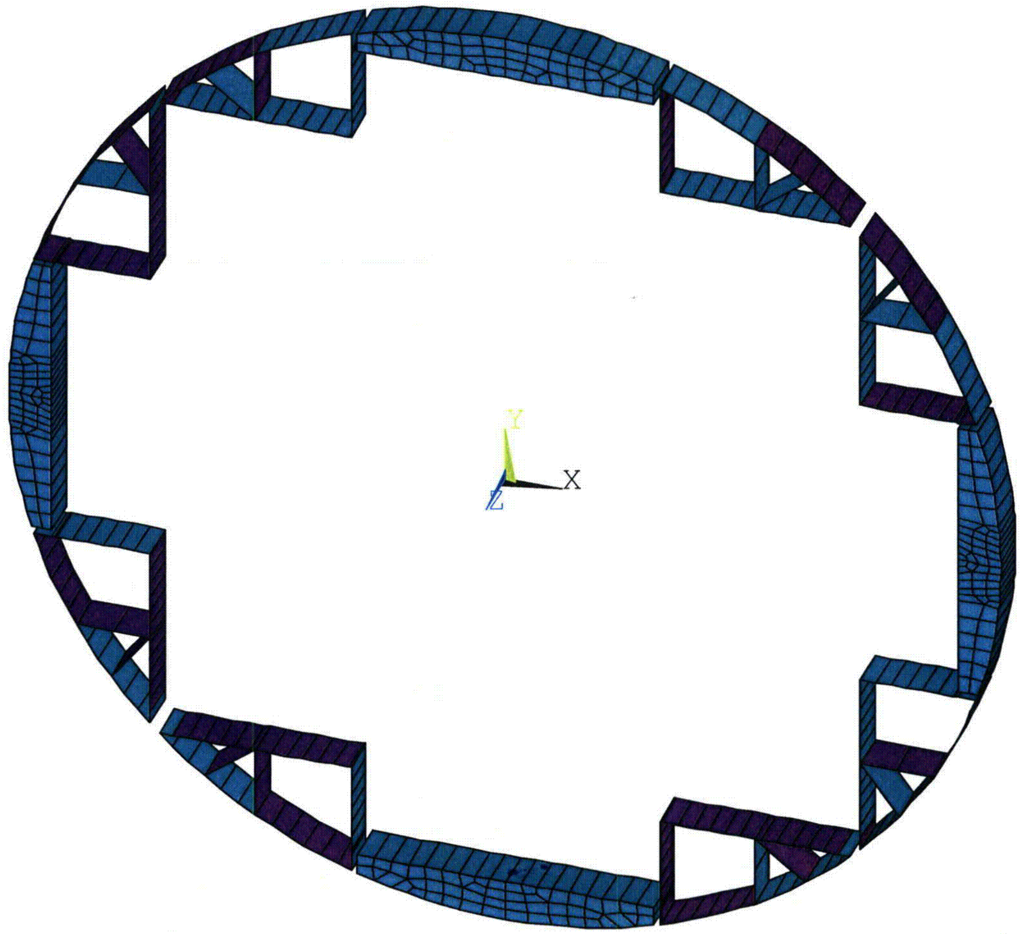


Figure T.3.6-6
Finite Element Model – Rails
(Type 2 Basket)

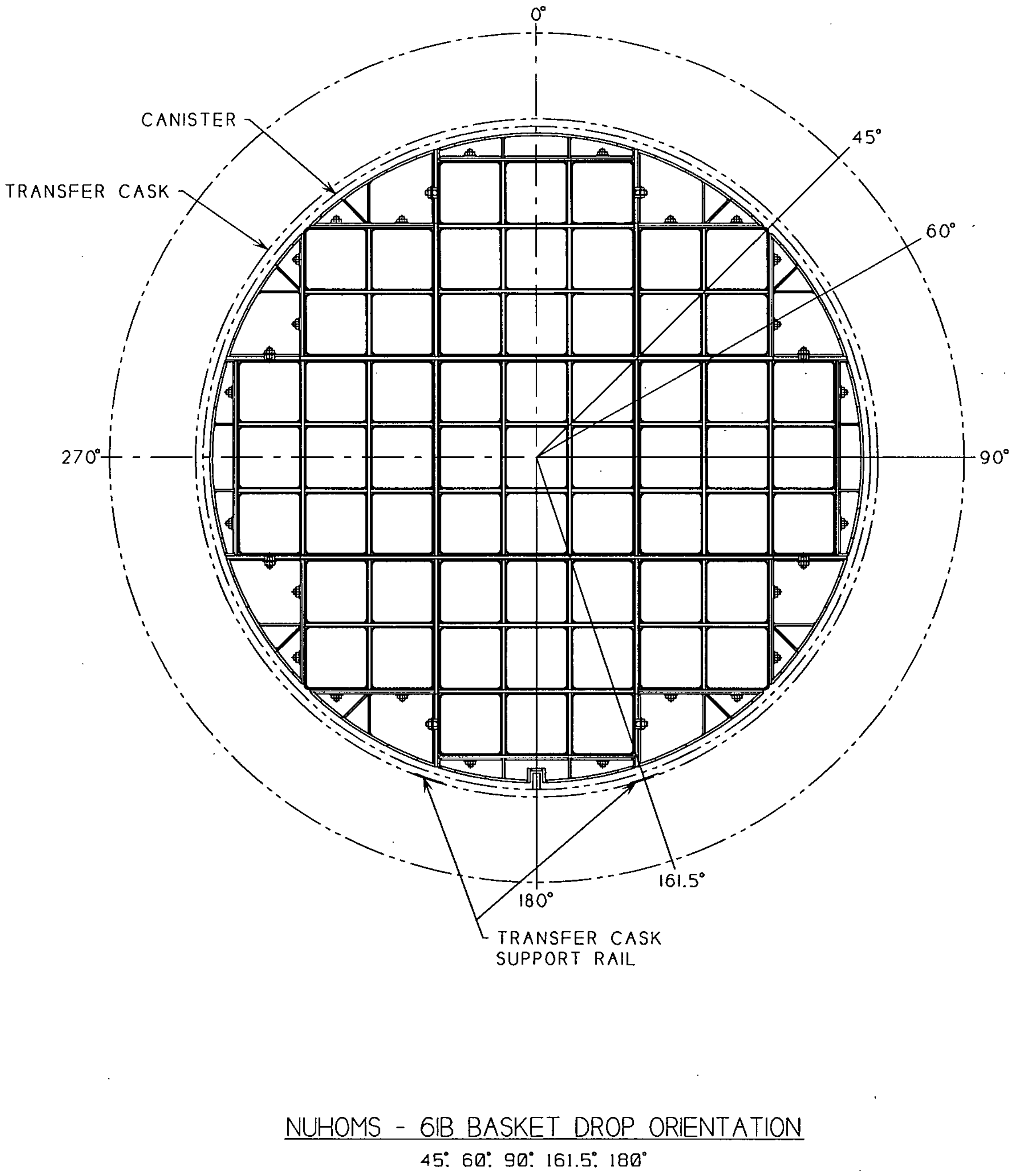


Figure T.3.6-7
NUHOMS®-61BTH Basket Drop Orientations
45°, 60°, 90°, 161.5°, 180°

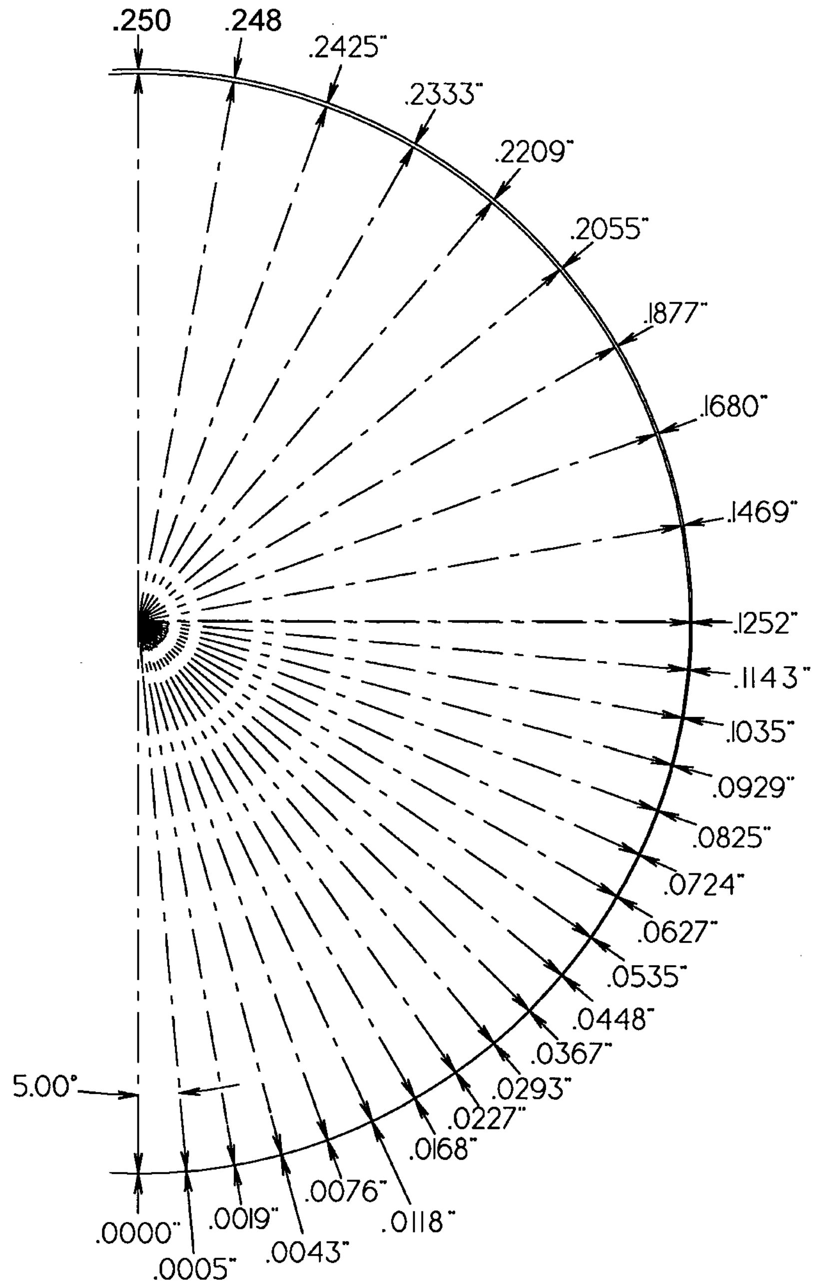


Figure T.3.6-8
Gap Sizes between Basket Rails and Canister Inner Surfaces

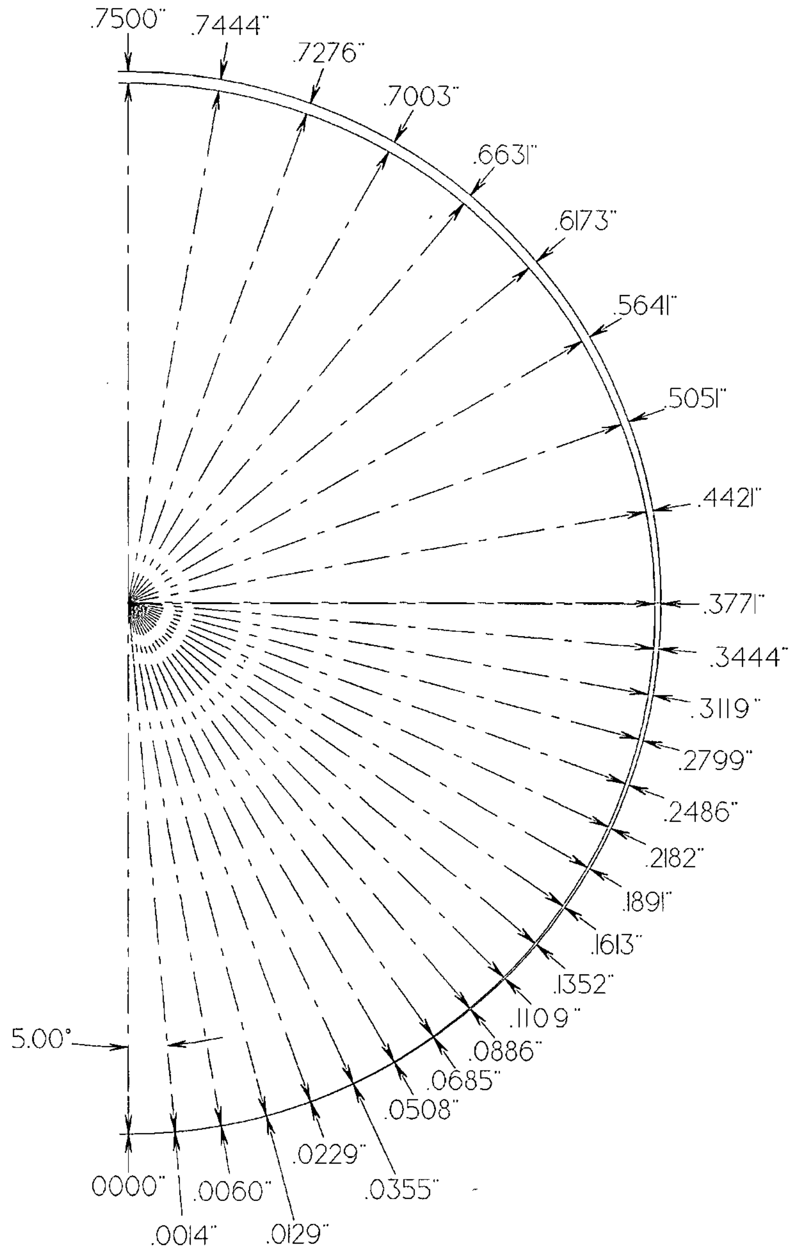


Figure T.3.6-9
Gap Sizes Between Canister Outer Surface and Cask Inner Surfaces

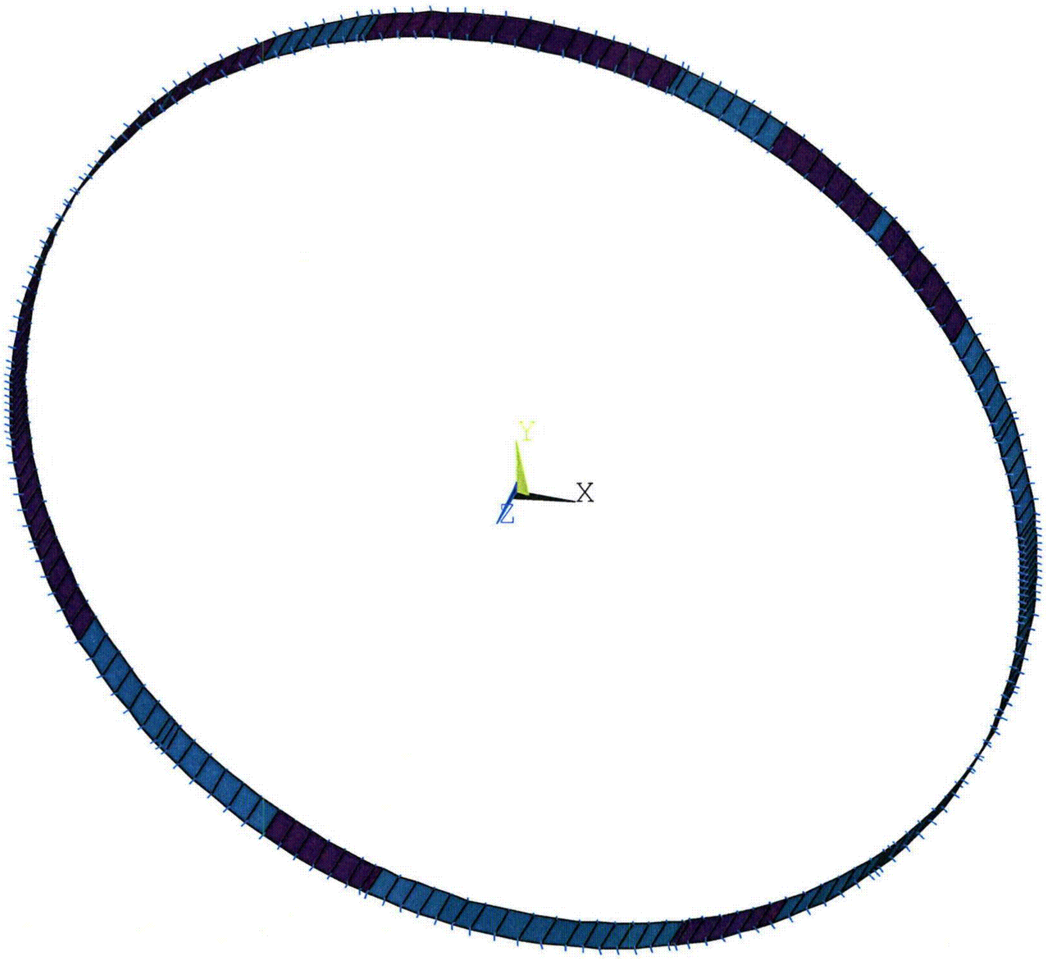


Figure T.3.6-10
Finite Element Model – Canister & Gaps

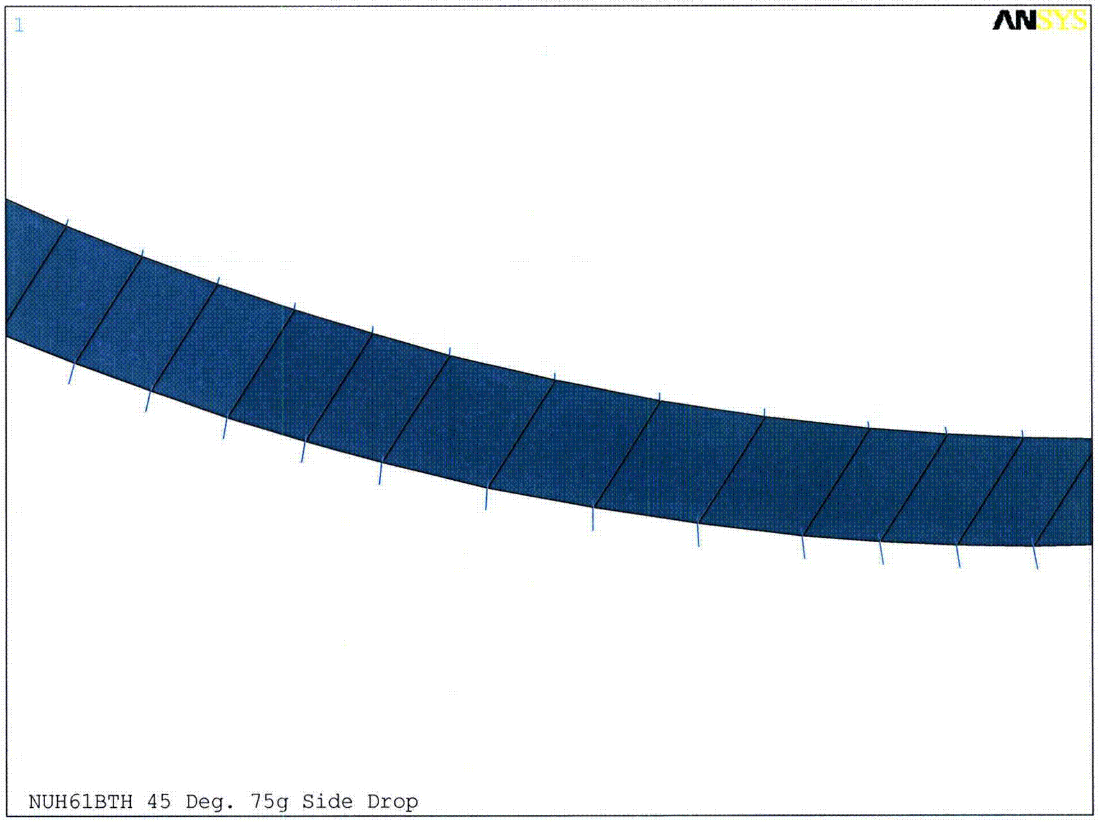


Figure T.3.6-11
Finite Element Model – Canister & Gaps, Enlarged View

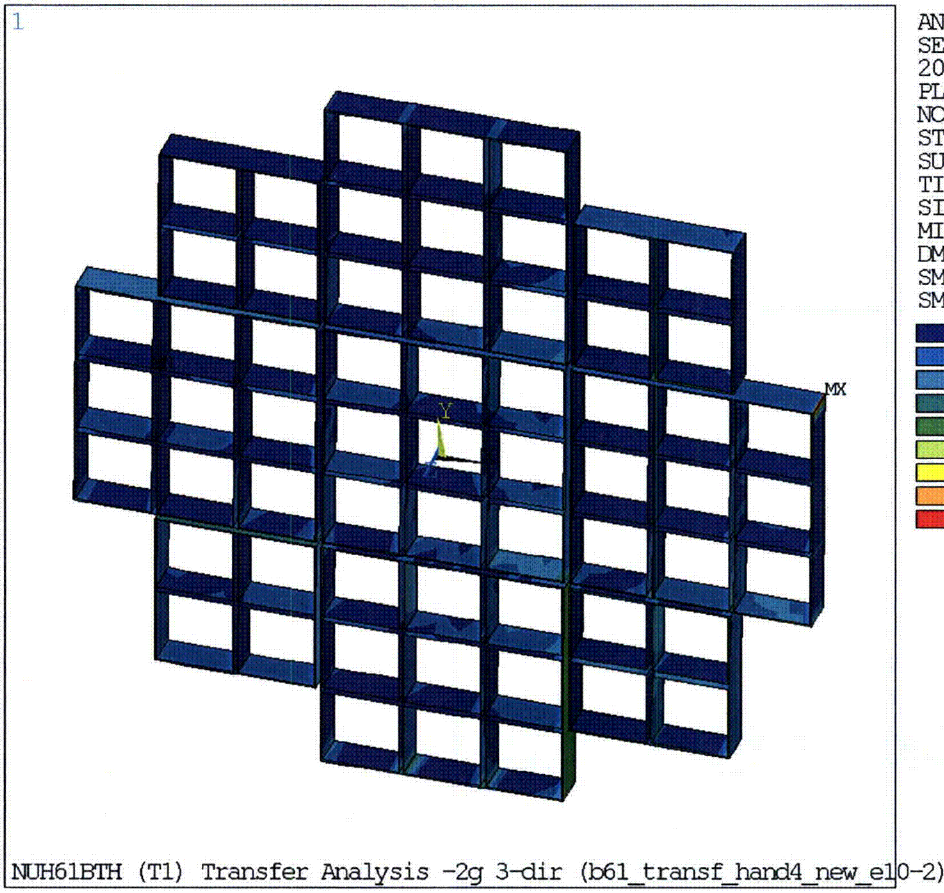


Figure T.3.6-12
Type 1 Basket, Membrane Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

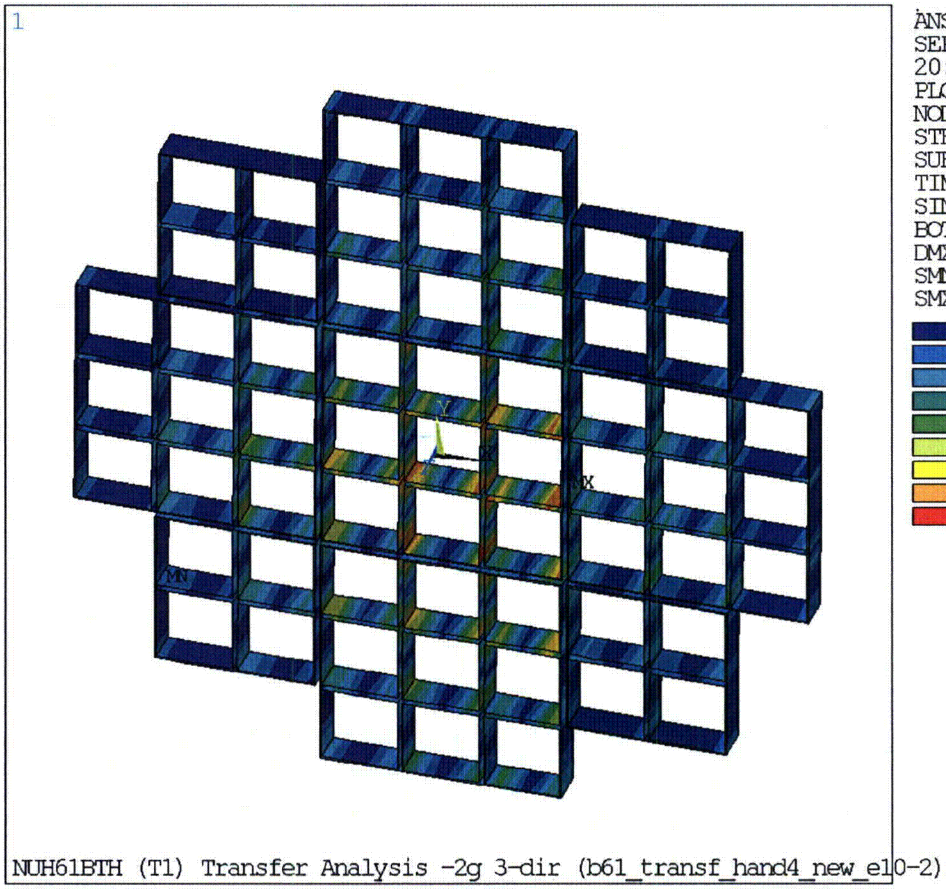


Figure T.3.6-13
Type 1 Basket, Membrane + Bending Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

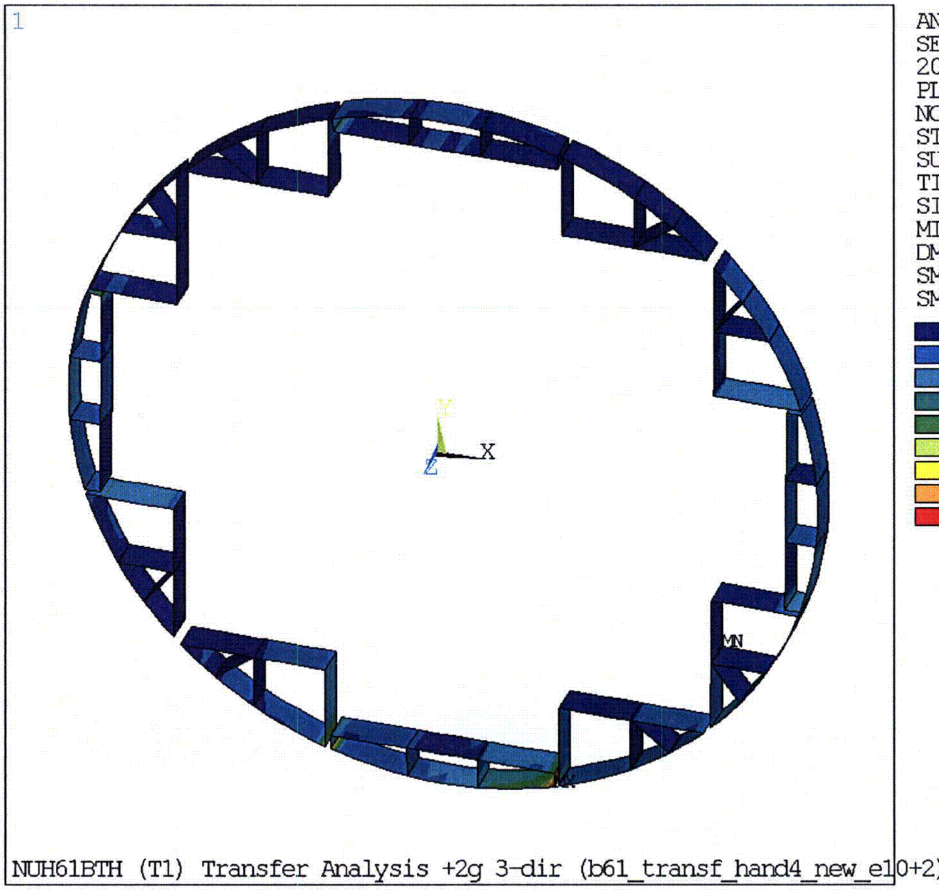


Figure T.3.6-14
Type 1 Rail, Membrane Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

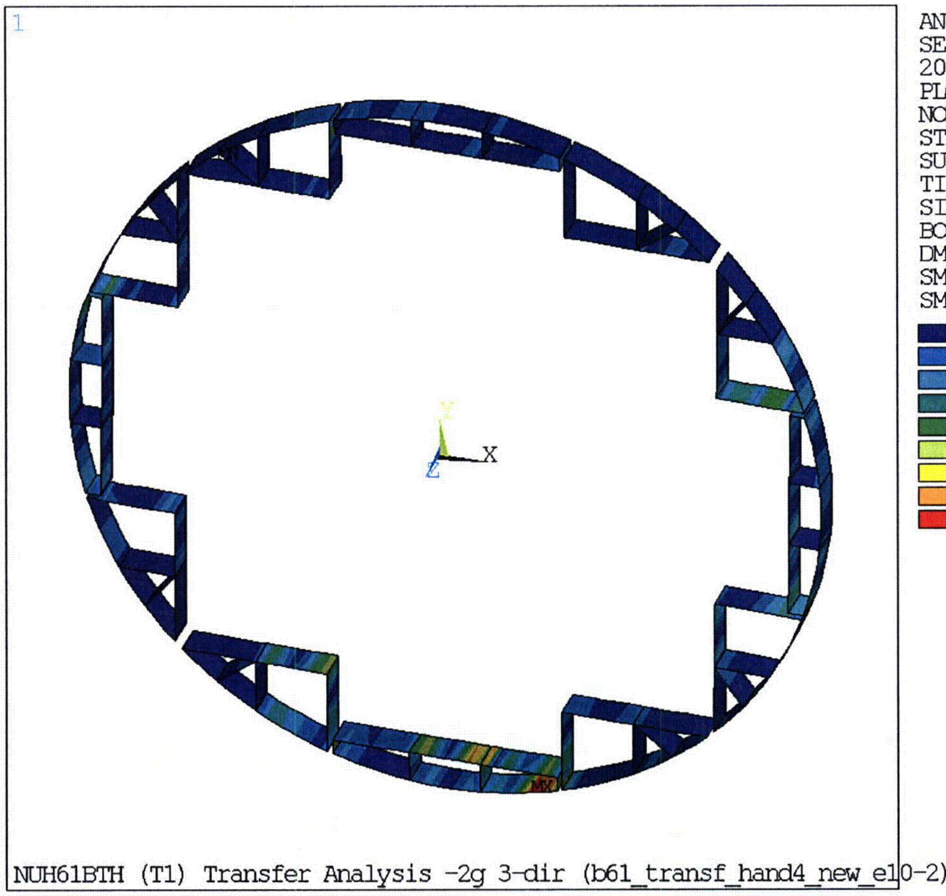


Figure T.3.6-15
Type 1 Rail, Membrane + Bending Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

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Figure T.3.6-16
Type 1 Canister Shell, Membrane Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

FIGURE DELETED

Figure T.3.6-17
Type 1 Canister Shell, Membrane + Bending Stress Intensity (psi)
(Handling / Transfer Load - 2g axial + 2g transverse + 2g vertical)

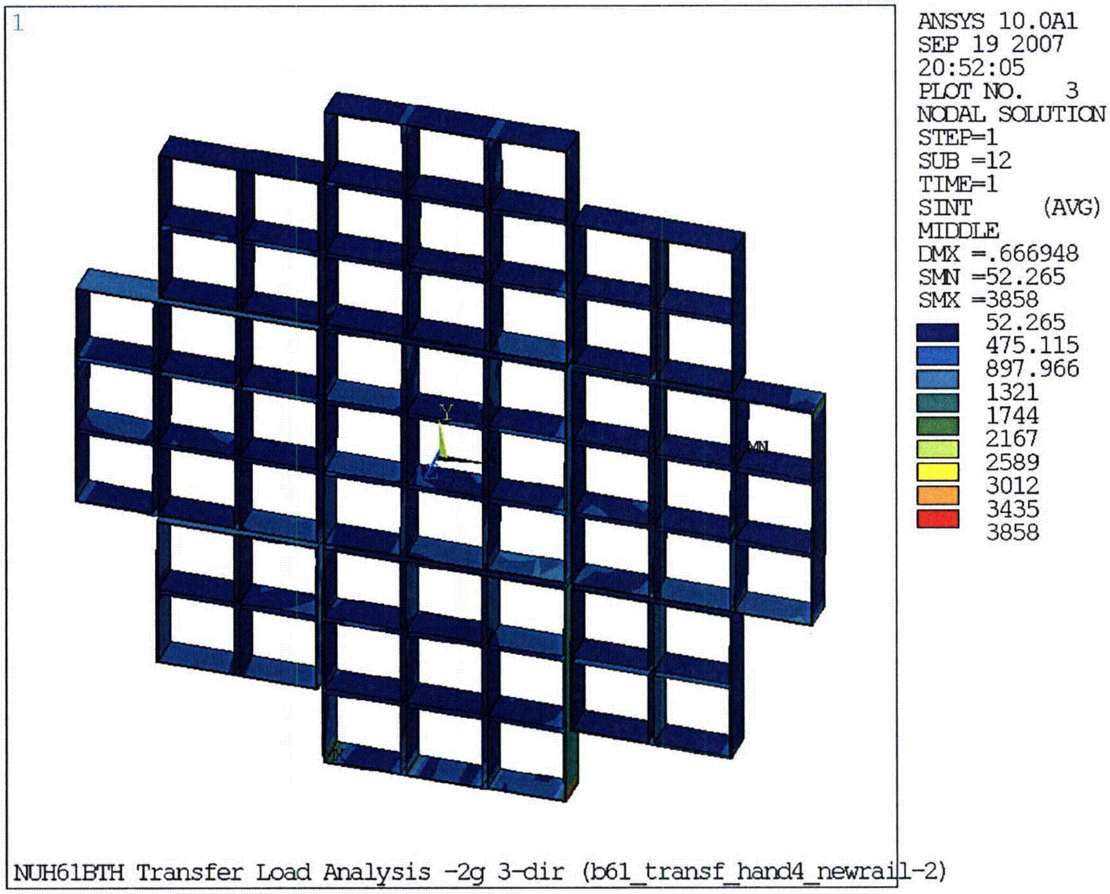

Figure T.3.6-18
Type 2 Basket Membrane Stress Intensity (psi)
(Handling/Transfer Load – 2g axial + 2g transverse + 2g vertical)

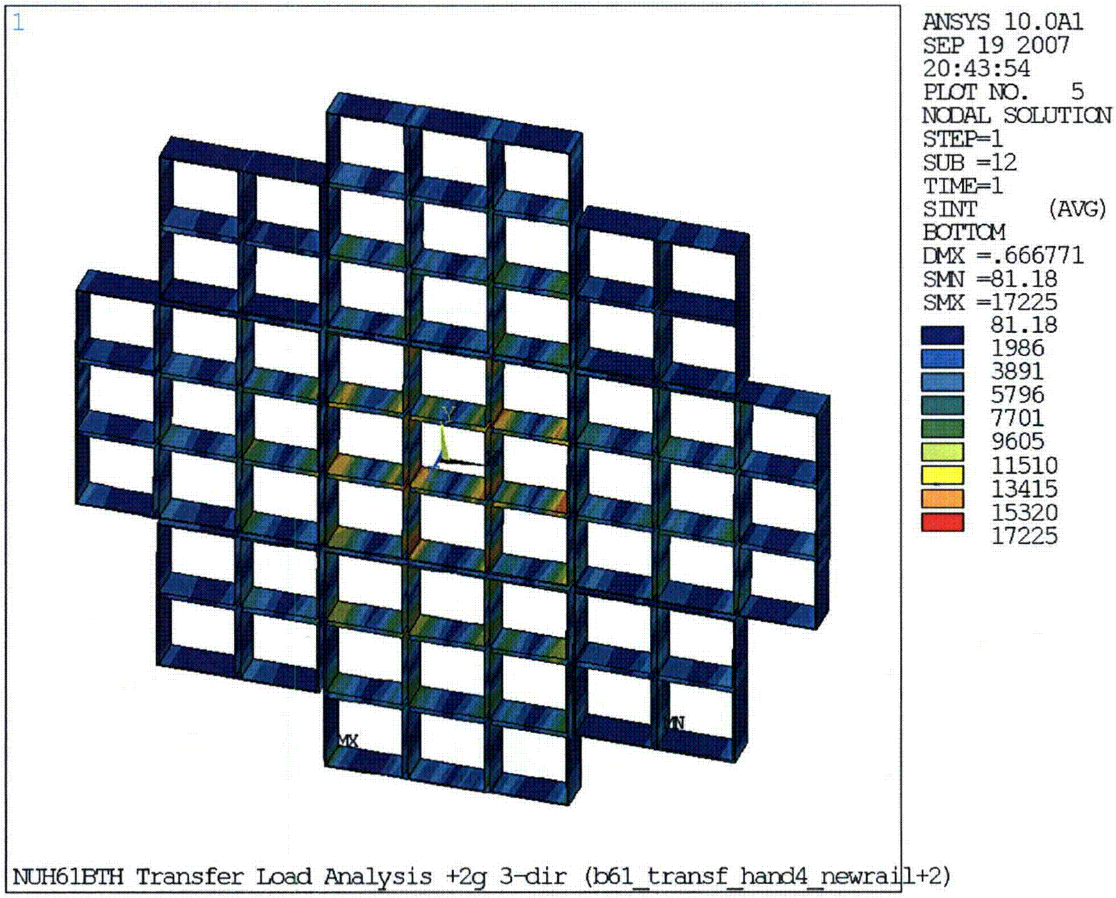

Figure T.3.6-19
Type 2 Basket Membrane + Bending Stress Intensity (psi)
(Handling/Transfer Load – 2g axial + 2g transverse + 2g vertical)

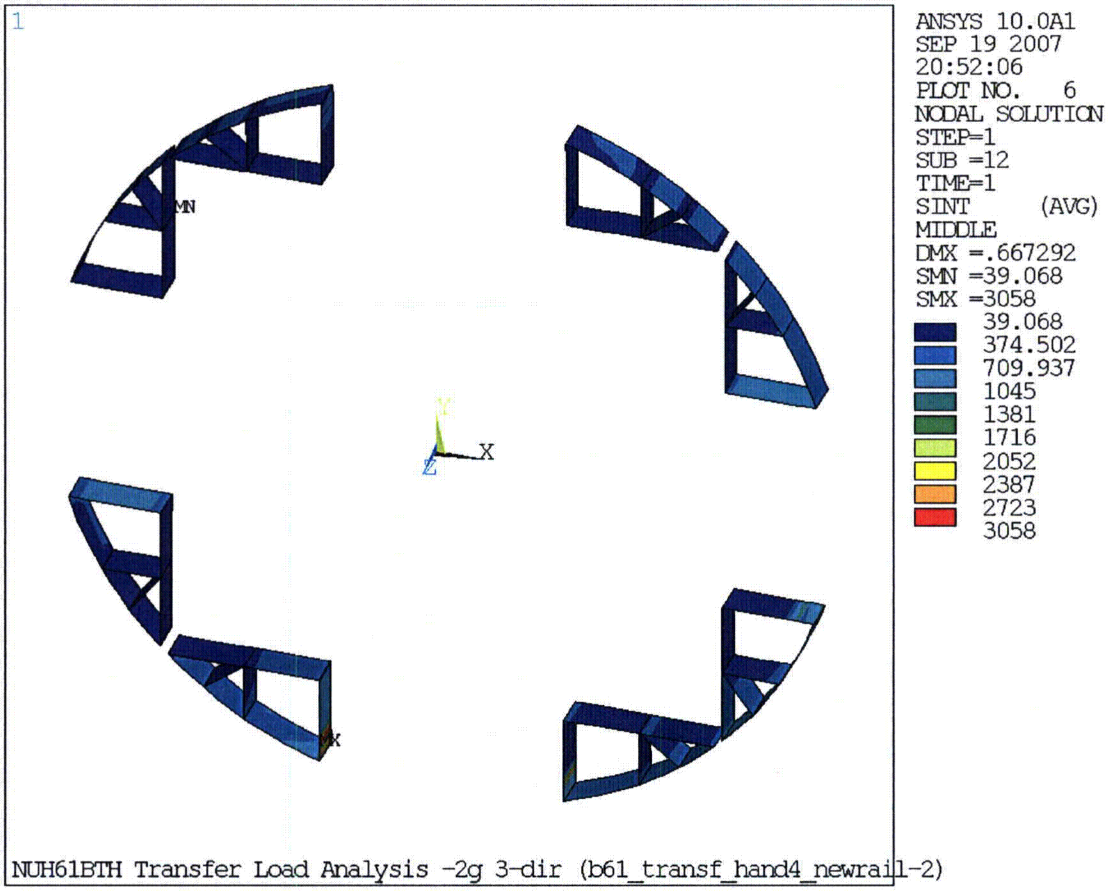

Figure T.3.6-20
Type 2 SST Rail Membrane Stress Intensity (psi)
(Handling/Transfer Load – 2g axial + 2g transverse + 2g vertical)

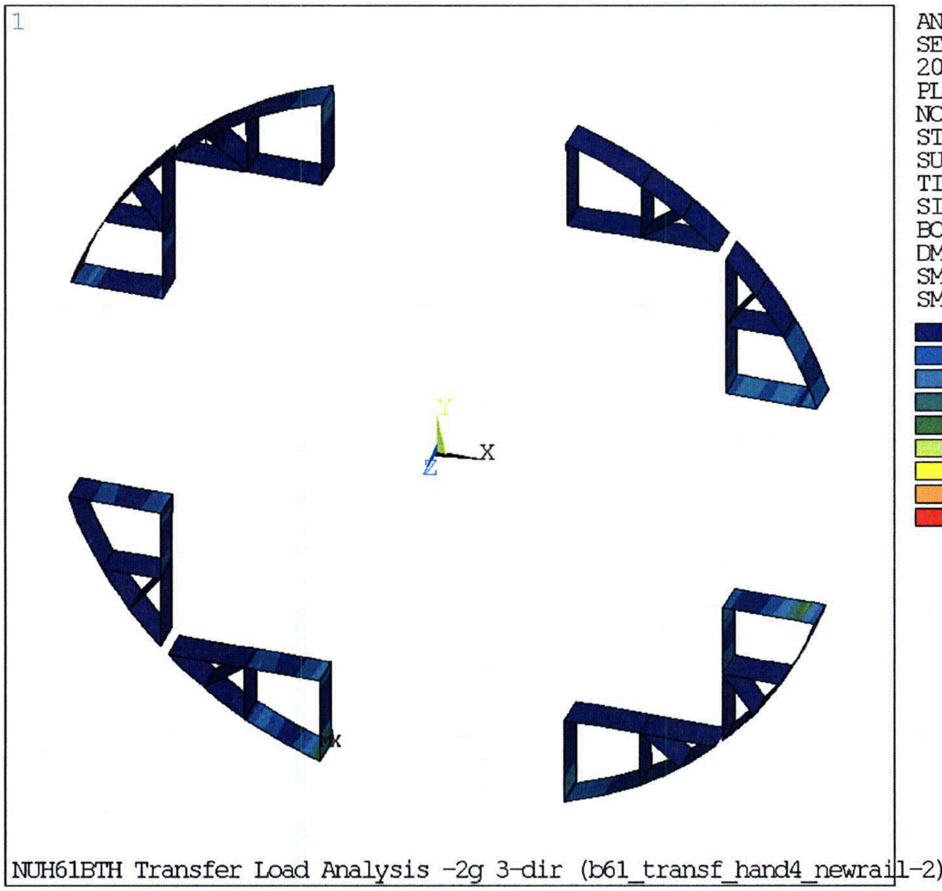

Figure T.3.6-21
Type 2 SST Rail Membrane + Bending Stress Intensity (psi)
(Handling/Transfer Load – 2g axial + 2g transverse + 2g vertical)

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Figure T.3.6-22
Type 2 Canister Shell, Membrane Stress Intensity (psi)
(Handling /Transfer Load – 2g axial + 2g transverse + 2g vertical)

FIGURE DELETED

Figure T.3.6-23
Type 2 Canister Shell, Membrane + Bending Stress Intensity (psi)
(Handling /Transfer Load – 2g axial + 2g transverse + 2g vertical)

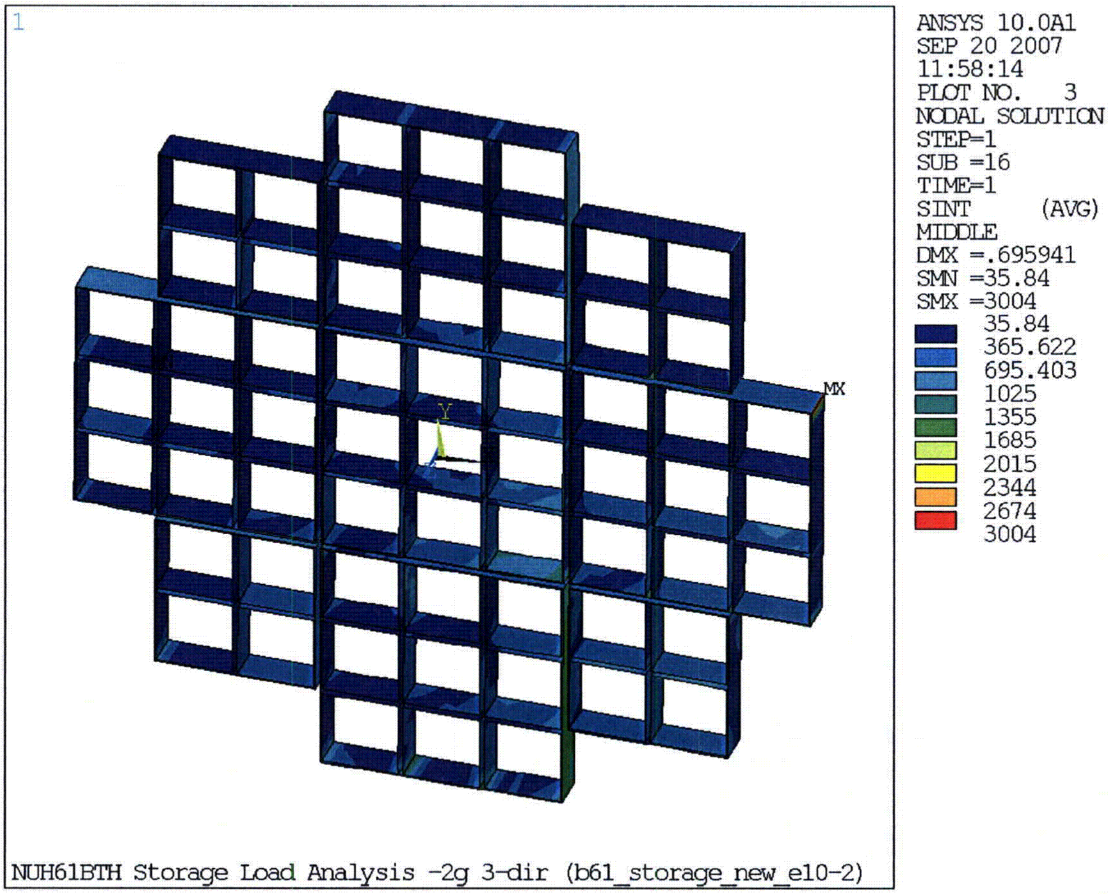

Figure T.3.6-24
Type 1 Basket, Membrane Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

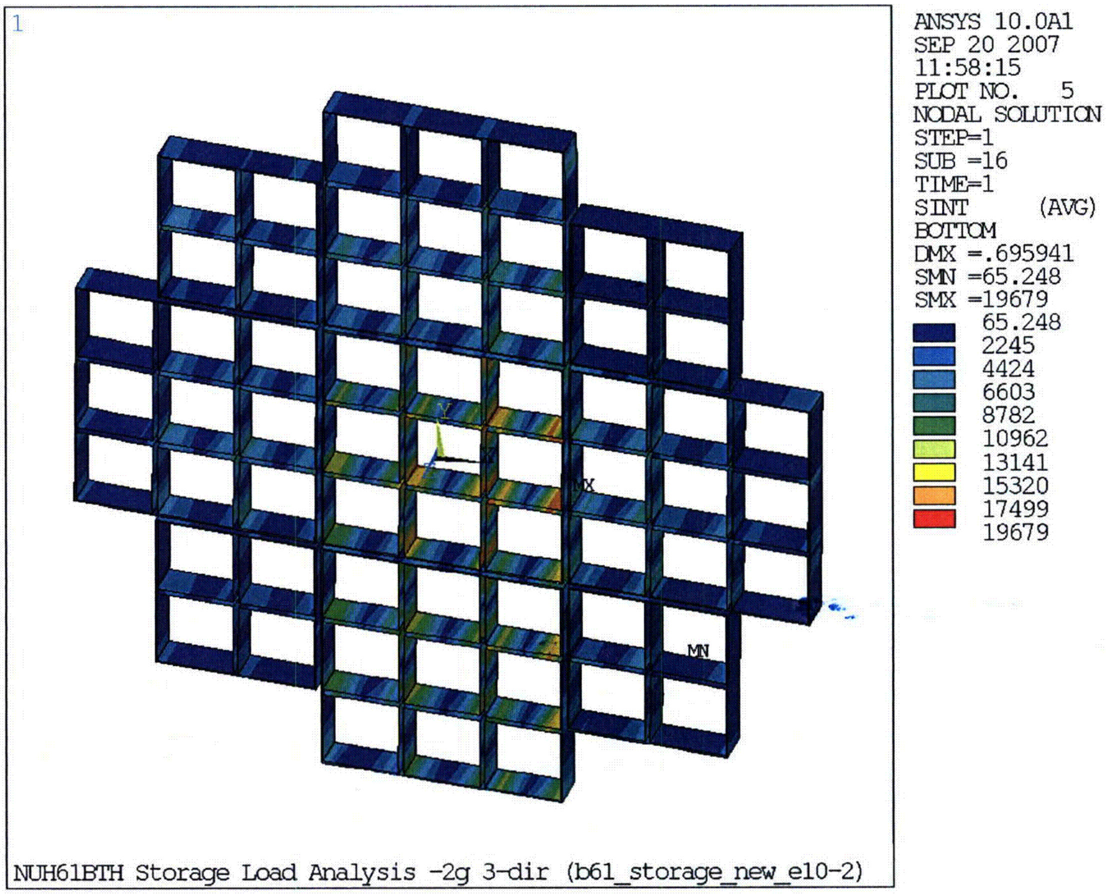

Figure T.3.6-25
Type 1 Basket, Membrane + Bending Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

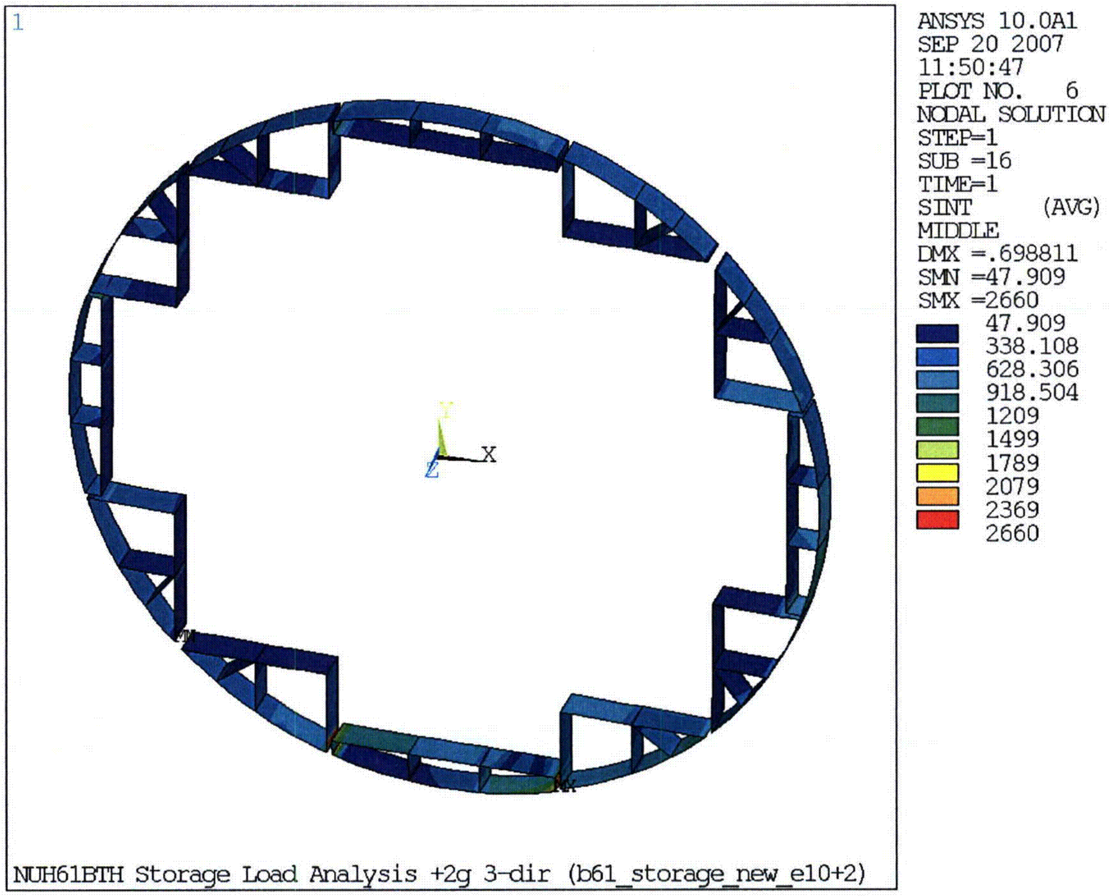

Figure T.3.6-26
Type 1 Rail, Membrane Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

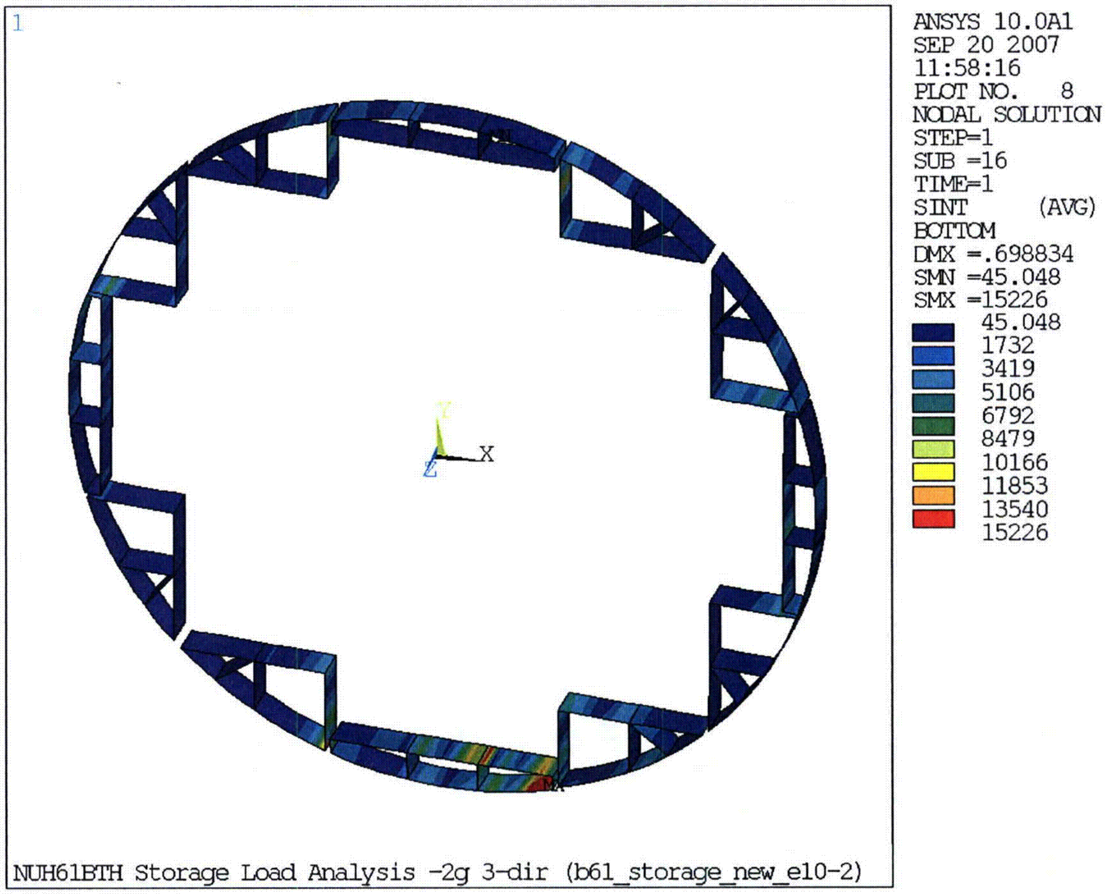

Figure T.3.6-27
Type 1 Rail, Membrane + Bending Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

FIGURE DELETED

Figure T.3.6-28
Type 1 Canister Shell, Membrane Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

FIGURE DELETED

Figure T.3.6-29
Type 1 Canister Shell, Membrane +Bending Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

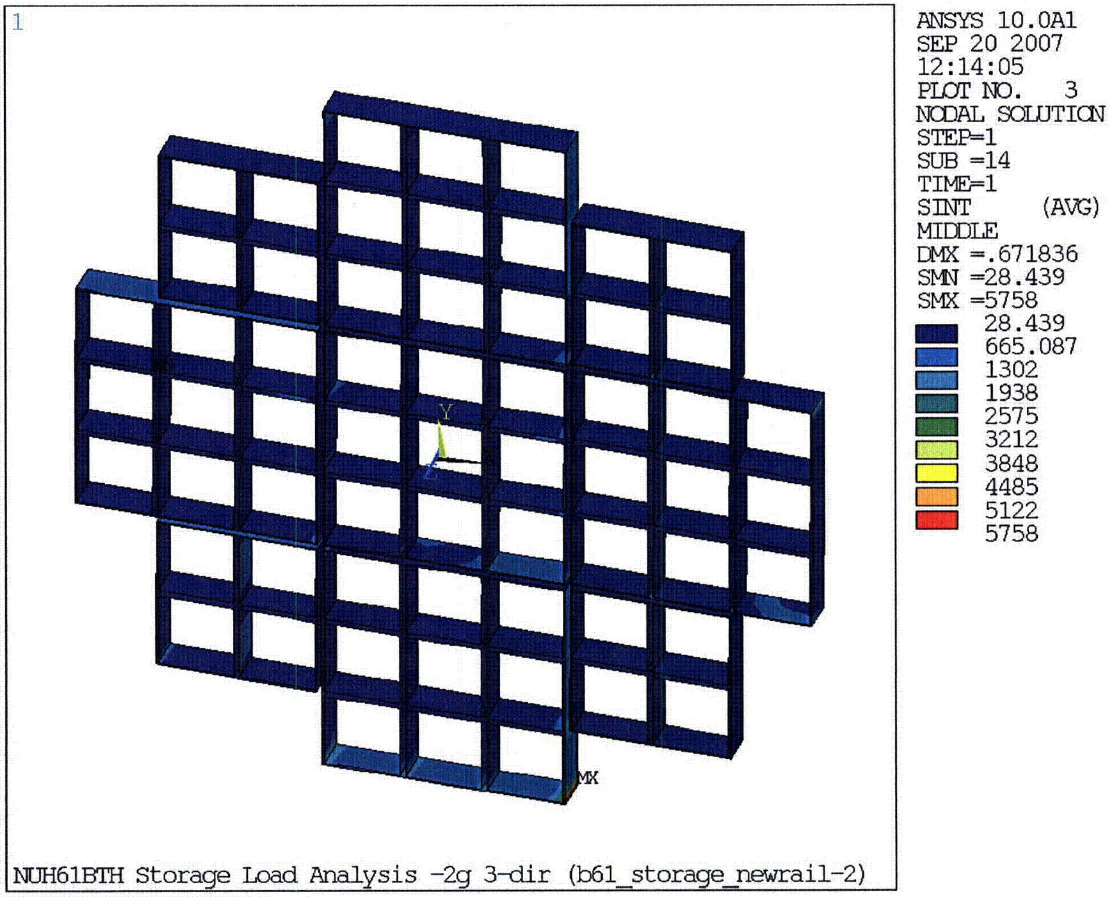

Figure T.3.6-30
Type 2 Basket, Membrane Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

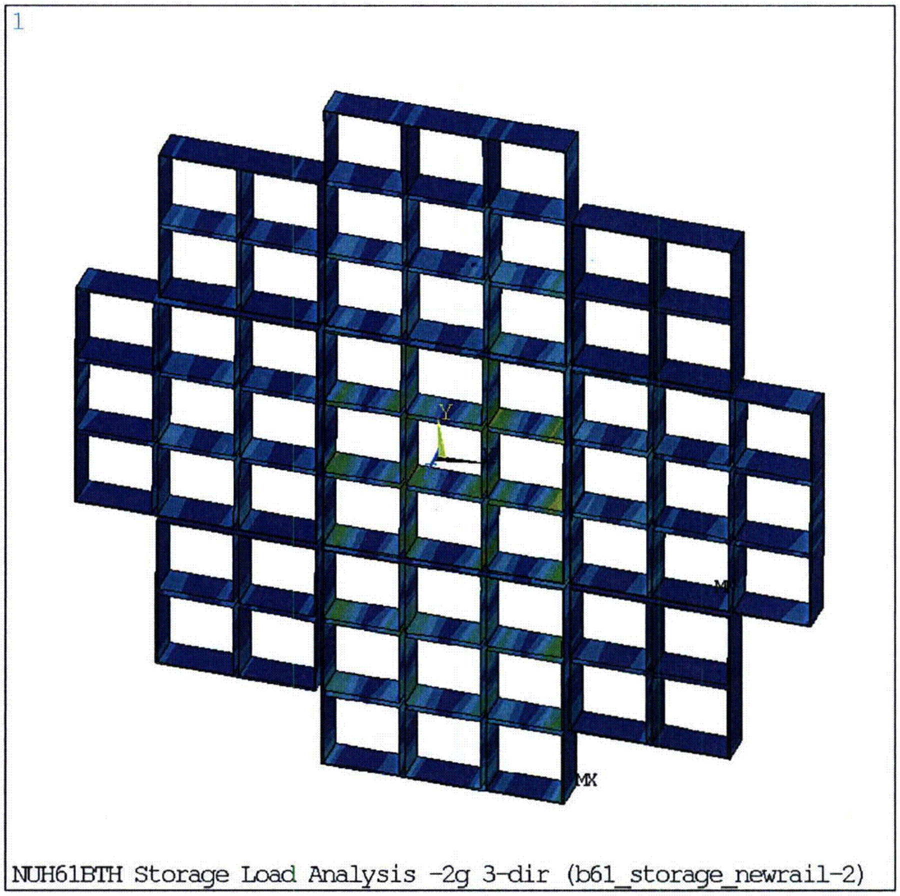

Figure T.3.6-31
Type 2 Basket, Membrane + Bending Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

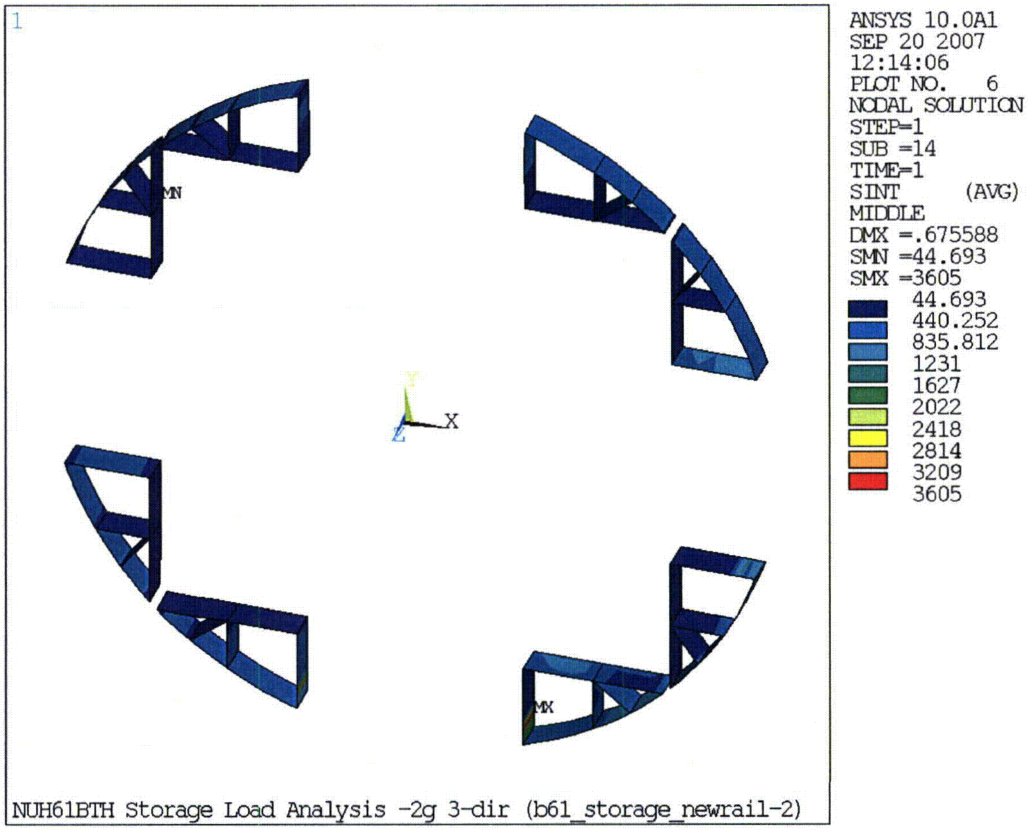

Figure T.3.6-32
Type 2 SST Rail, Membrane Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

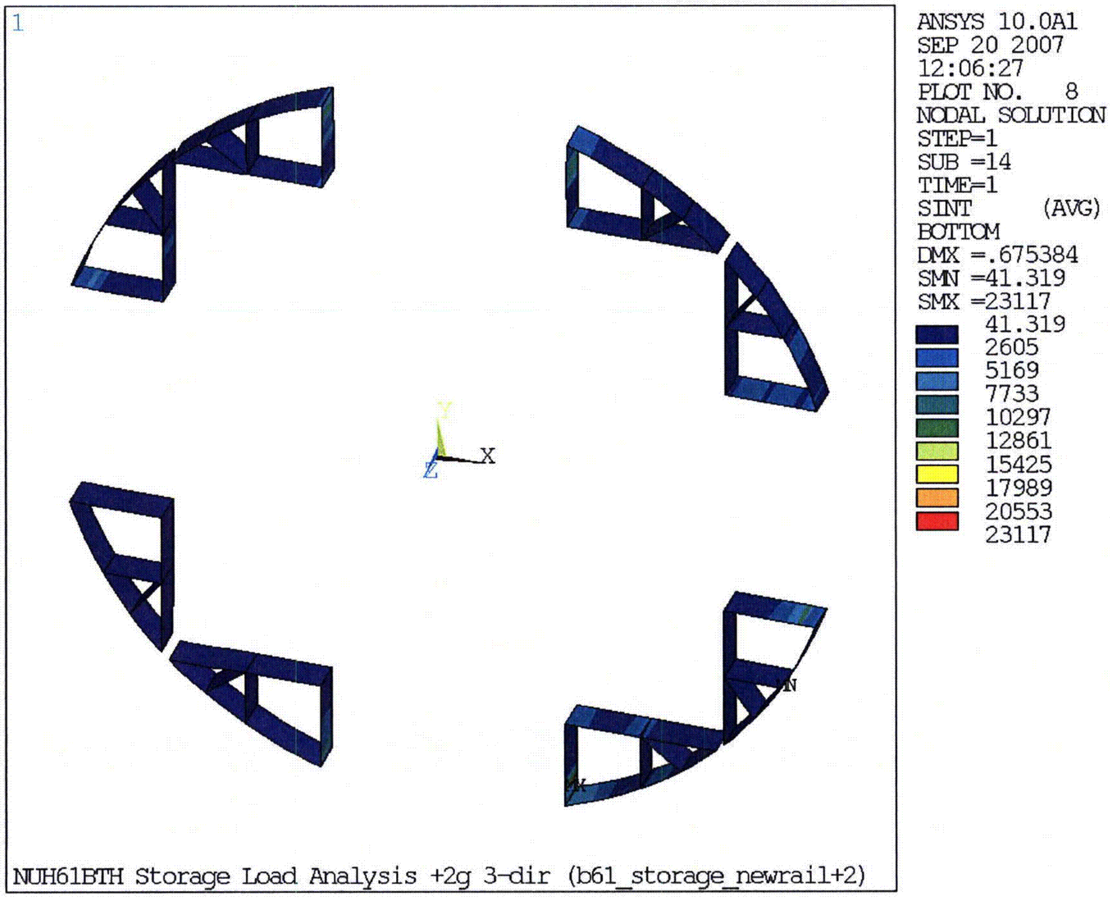

Figure T.3.6-33
Type 2 SST Rail, Membrane + Bending Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

FIGURE DELETED

Figure T.3.6-34
Type 2 Canister Shell, Membrane Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

FIGURE DELETED

Figure T.3.6-35
Type 2 Canister Shell, Membrane + Bending Stress Intensity (psi)
(Orientation / Storage Load – 2g axial + 2g transverse + 2g vertical)

Proprietary Information withheld from pages T.3.6-78 through T.3.6-90 under 10 CFR 2.390