Table of Contents (Continued)

2.6.13.7 Stress Evaluation of the Yankee-MPC Canister for Thermal Plus a 1-Foot Side Drop Load Condition 2.6.13.7-1
2.6.13.8 Yankee-MPC Canister Shear Stresses for a 1-Foot Side Drop and a 1-Foot End Drop Condition 2.6.13.8-1
2.6.13.9 Yankee-MPC Canister Bearing Stresses for 1-Foot Side Drop 2.6. 13.9-1
2.6.13.10 Yankee-MPC Canister Buckling Evaluation for 1-Foot End Drop 2.6.13.10-1
2.6.13.11 Yankee-MPC Canister Lifting Evaluation 2.6.13.11-1
2.6.13.12 Yankee-MPC Canister Closure Weld Evaluation – Normal Conditions 2.6.13.12.1
2.6.14 Yankee-MPC Fuel Basket Analysis - Normal Conditions of Transport ... 2.6.14-1
2.6.14.1 Detailed Analysis - Yankee-MPC Fuel Basket 2.6.14-6
2.6.14.2 Finite Element Model Description - Yankee-MPC Fuel Basket 2.6. 14-8
2.6.14.3 Thermal Expansion Evaluation of Yankee-MPC Fuel Basket Support Disk ..... 2.6. 14 -24
2.6.14.4 Stress Evaluation of Yankee-MPC Fuel Basket Support Disk for a 1-Foot End Drop Condition 2.6.14-26
2.6.14.5 Stress Evaluation of Yankee-MPC Fuel Basket Support Disk for Thermal Plus a 1-Foot End Drop Combined Condition .. 2.6.14-31
2.6.14.6 Stress Evaluation of Yankee-MPC Basket Tie Rods and Spacers for a 1-Foot End Drop Load Condition 2.6.14-34
2.6.14.7 Stress Evaluation of Yankee-MPC Fuel Basket Support Disk for a 1-Foot Side Drop Load Condition 2.6.14-35
2.6.14.8 Stress Evaluation of Yankee-MPC Fuel Basket Support Disk for Thermal Plus a 1-Foot Side Drop Combined Condition . 2.6.14-49
2.6.14.9 Yankee-MPC Fuel Basket Support Disk Shear Stresses for 1-Foot Drops 2.6.14-55
2.6.14.10 Bearing Stress - Basket Contact with Canister Shell 2.6.14-55
2.6.14.11 Yankee-MPC Fuel Basket Weldment Analysis for 1-Foot End Drop 2.6.14-56
2.6.14.12 Yankee-MPC Fuel Basket Support Disk - Buckling Evaluation (Normal Conditions of Transport) 2.6.14-60

Table of Contents (Continued)

2.6.15 CY-MPC Transportable Storage Canister Analysis – Normal Conditions of Transport 2.6.15-1
2.6.15.1 Analysis Description – CY-MPC Canister 2.6.15.1-1
2.6.15.2 Finite Element Model Description – CY-MPC Canister 2.6.15.2-1
2.6.15.3 Thermal Expansion of CY-MPC Canister Containing Fuel 2.6.15.3-1
2.6.15.4 Stress Evaluation of the CY-MPC Canister for 1-Foot End Drop Load Condition 2.6.15.4-1
2.6.15.5 Stress Evaluation of the Canister for Thermal Plus a 1-Foot End Drop Load Condition 2.6.15.5-1
2.6.15.6 Stress Evaluation of the Canister for a 1-Foot Side Drop Load Condition 2.6.15.6-1
2.6.15.7 Stress Evaluation of the CY-MPC Canister for Thermal Plus a 1-Foot Side Drop Load Condition 2.6.15.7-1
2.6.15.8 CY-MPC Canister Shear Stresses for a 1-Foot Side Drop and a 1-Foot End Drop Condition 2.6.15.8-1
2.6.15.9 CY-MPC Canister Bearing Stresses for a 1-Foot Side Drop 2.6.15.9-1
2.6.15.10 CY-MPC Canister Buckling Evaluation for 1-Foot End Drop 2.6.15.10-1
2.6.15.11 CY-MPC Canister Lifting Evaluation 2.6.15.11-1
2.6.15.12 CY-MPC Canister Closure Weld Evaluation – Normal Conditions of Transport 2.6.15.12-1
2.6.16 CY-MPC Fuel Basket Analysis – Normal Conditions of Transport 2.6.16-1
2.6.16.1 Detailed Analysis of the CY-MPC Fuel Basket 2.6.16-7
2.6.16.2 CY-MPC Fuel Basket Finite Element Model Description 2.6.16-9
2.6.16.3 Thermal Expansion Evaluation of the CY-MPC Support Disk 2.6.16-20
2.6.16.4 Stress Evaluation of the CY-MPC Support Disk for a 1-Foot End Drop 2.6.16-23
2.6.16.5 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot End Drop Load Condition 2.6.16-26

Table of Contents (Continued)

2.6.16.6 Stress Evaluation of CY-MPC Tie Rods and Spacers for 1-Foot End Drop 2.6.16-29
2.6.16.7 Stress Evaluation of CY-MPC Support Disk for a 1-Foot Side Drop 2.6.16-32
2.6.16.8 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot Side Drop Load Condition . 2.6.16-44
2.6.16.9 CY-MPC Support Disk Shear Stresses for 1-Foot Drop 2.6.16-51
2.6.16.10 Bearing Stress – Basket Contact with Canister Shell – CY-MPC 2.6.16-51
2.6.16.11 CY-MPC Fuel Basket Weldment Analysis for 1-Foot End Drop 2.6.16-52
2.6.16.12 CY-MPC Fuel Basket Support Disk – Buckling Evaluation 2.6.16-56
2.6.16.13 Stress Evaluation of the CY-MPC Support Disk for 1-Foot Oblique Drop 2.6.16-58
2.6.16.14 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot Oblique Drop Load Condition 2.6.16-60

2.6.17 CY-MPC Reconfigured Fuel Assembly Analysis and Damaged Fuel Can Analysis – Normal Conditions of Transport 2.6.17-1
2.6.17.1 CY-MPC Reconfigured Fuel Assembly Evaluation 2.6.17-1
2.6.17.2 CY-MPC Damaged Fuel Can Evaluation 2.6.17-8

2.6.18 Spacer Design for Canistered Fuel – Normal Conditions of Transport 2.6.18-1
2.6.18.1 Spacer Evaluation for Yankee-MPC Canister Fuel and GTCC Waste 2.6.18-1
2.6.18.2 Spacer Evaluation for CY-MPC Canister Fuel and GTCC Waste 2.6.18-2

2.6.19 Greater Than Class C (GTCC) Basket Analysis – Normal Conditions of Transport 2.6.19-1
2.6.19.1 Yankee-MPC GTCC Basket Analysis 2.6.19-1
2.6.19.2 CY-MPC GTCC Basket Analysis 2.6.19-6

Table of Contents (Continued)

2.7 Hypothetical Accident Conditions 2.7-1
2.7.1 Free Drop (30 Feet) 2.7.1-1
2.7.1.1 Thirty-Foot End Drop 2.7.1.1-1
2.7.1.2 Thirty-Foot Side Drop 2.7.1.2-1
2.7.1.3 Thirty-Foot Corner Drop 2.7.1.3-1
2.7.1.4 Thirty-Foot Oblique Drop 2.7.1.4-1
2.7.1.5 Lead Slump Resulting From a Cask Drop Accident 2.7.1.5-1
2.7.1.6 Closure Analysis - Hypothetical Accident Conditions 2.7.1.6-1
2.7.2 Puncture 2.7.2-1
2.7.2.1 Puncture - Cask Side Midpoint 2.7.2.1-1
2.7.2.2 Puncture - Center of Outer Lid 2.7.2.2-1
2.7.2.3 Puncture - Center of Cask Bottom 2.7.2.3-1
2.7.2.4 Puncture - Port Cover 2.7.2.4-1
2.7.2.5 Puncture Accident - Shielding Consequences 2.7.2.5-1
2.7.2.6 Puncture - Conclusion 2.7.2.6-1
2.7.3 Thermal 2.7.3.1-1
2.7.3.1 Discussion 2.7.3.1-1
2.7.3.2 Pressure Stress Evaluation 2.7.3.2-1
2.7.3.3 Thermal Stress Evaluation 2.7.3.3-1
2.7.3.4 Bolts - Closure Lids (Thermal Accident) 2.7.3.4-1
2.7.3.5 Performance Summary - Thermal Accident 2.7.3.5-1
2.7.3.6 Conclusion 2.7.3.6-1
2.7.4 Crush 2.7.4-1
2.7.5 Immersion - Fissile Material 2.7.5-1
2.7.6 Immersion - All Packages 2.7.6-1
2.7.7 Damage Summary 2.7.7-1
2.7.8 Directly Loaded Fuel Basket Analysis - Accident Conditions 2.7.8-1

Table of Contents (Continued)

2.10.3 LS-DYNA Computer Code 2.10.3-1
2.10.3.1 Predicting Impact Deceleration using Strain Rate Sensitive Properties 2.10.3-1
2.10.3.2 Accounting for Strain Rate Sensitivity by Interpolation 2.10.3-2
2.10.4 Detailed Finite Element Stress Summaries - Directly Loaded Fuel Configuration 2.10.4-1
2.10.5 Inner Shell Buckling Analysis 2.10.5-1
2.10.5.1 Buckling Analysis 2.10.5-1
2.10.5.2 Analysis Results 2.10.5-2
2.10.5.3 Verification of the Code Case N-284 Buckling Evaluation of the NAC-STC Inner Shell and Transition Sections 2.10.5-3
2.10.5.4 Buckling Evaluation of the Inner Shell for the Yankee-MPC Fuel Configuration 2.10.5-9
2.10.5.5 Buckling Evaluation of the Inner Shell for the CY-MPC Fuel Configuration 2.10.5-14
2.10.6 Scale Model Test Program for the NAC-STC 2.10.6-1
2.10.6.1 Introduction 2.10.6-1
2.10.6.2 Purpose 2.10.6-2
2.10.6.3 Discussion 2.10.6-2
2.10.6.4 Eighth-Scale Redwood Impact Limiter Compression Tests 2.10.6-9
2.10.6.5 Quarter-Scale Model Drop Tests 2.10.6-14
2.10.6.6 NAC-STC Quarter-Scale Model Drawings 2.10.6-41
2.10.6.7 NAC-STC Eighth-Scale Model Drawings 2.10.6-42
2.10.7 Redwood Impact Limiter Force-Deflection Curves and Data – Directly Loaded Fuel Configuration 2.10.7-1
2.10.7.1 Potential Energy and Cask Drop Impact Motion 2.10.7-1
2.10.7.2 Conversion of Potential Energy to Kinetic Energy 2.10.7-9
2.10.7.3 Deceleration Forces and Energy Absorption Calculation 2.10.7-10
2.10.7.4 RBCUBED Calculated Force-Deflection Graphs 2.10.7-13
2.10.8 Bolts - Closure Lids (Stress Evaluations) 2.10.8-1
2.10.8.1 Analysis Approach 2.10.8-1
2.10.8.2 Inner Lid Closure Bolt Analyses 2.10.8-2
2.10.8.3 Outer Lid Closure Bolt Analyses 2.10.8-15

Table of Contents (Continued)

2.10.9 Lead Slump Evaluation 2.10.9-1
2.10.9.1 Methodology/Finite Element Analysis 2.10.9-2
2.10.9.2 Analysis Result 2.10.9-3
2.10.9.3 Conclusion 2.10.9-5
2.10.10 Assessment of the Effect of the Revised Temperature Distribution on Structural Qualification 2.10.10-1
2.10.10.1 Evaluation Methodology 2.10.10-1
2.10.10.2 Temperature Dependent Stress Results 2.10.10-3
2.10.10.3 Conclusions - Revised Temperature Distribution Evaluation 2.10.10-7
2.10.11 Sensitivity Studies of the Yankee-MPC Canistered Fuel Basket Analysis 2.10.11-1
2.10.11.1 Yankee-MPC Fuel Basket Drop Orientation 2.10.11-1
2.10.11.2 Gap Stiffness 2.10.11-2
2.10.11.3 Finite Element Mesh for the Support Disk Ligaments 2.10.11-3
2.10.12 Confirmatory Testing Program –Balsa Impact Limiters and Attachments 2.10.12-1
2.10.12.1 Confirmatory Testing Program Results Summary 2.10.12-1
2.10.12.2 Acceptance Criteria for Model Performance 2.10.12-3
2.10.12.3 Description of 30-Foot Drop Tests Performed at SNL 2.10.12-4
2.10.12.4 Results/Evaluation for the 30-Foot Side Drop Test 2.10.12-8
2.10.12.5 Results/Evaluation for the 30-Foot Top Corner Drop Test 2.10.12-10
2.10.12.6 Results/Evaluation for the 30-Foot Top End Drop Test 2.10.12-12
2.10.12.7 LS-DYNA Analyses of the NAC-STC Quarter-Scale Model 2.10.12-14

List of Figures

Figure 2.3.6-1	Quasi-Static True Stress-Strain Curves for Chemical Copper Lead in Compression	2.3.6-2
Figure 2.3.6-2	Neutron Shield Thermal Expansion Coefficient	2.3.6-3
Figure 2.5.1-1	Lifting Trunnion Geometry	2.5.1-28
Figure 2.5.1-2	Trunnion Weld Geometry	2.5.1-29
Figure 2.5.1-3	Sling Inclination Angle for Outer Lid Lifting	2.5.1-30
Figure 2.5.1-4	Sling Inclination Angle for Inner Lid Lifting	2.5.1-31
Figure 2.5.1-5	Canister Lift Finite Element Model	2.5.1-32
Figure 2.5.1-6	Yankee-MPC Canister Lift Model Stress Intensity Contours (psi)	2.5.1-33
Figure 2.5.1-7	CY-MPC Canister Lift Model Stress Intensity Contours (psi)	2.5.1-34
Figure 2.5.2-1	Front Support and Tiedown Geometry	2.5.2-26
Figure 2.5.2-2	Free Body Diagram of Cask Subjected to Lateral Load	2.5.2-27
Figure 2.6.7.2-1	Section Locations for Stress Evaluation (Canister Configurations)	2.6.7.2-15
Figure 2.6.7.2-2	Yankee-MPC Cask Model with Pressure Distribution Applied (Side Drop Case)	2.6.7.2-16
Figure 2.6.7.2-3	CY-MPC Model with Pressure Distribution Applied (Side Drop Case)	2.6.7.2-17
Figure 2.6.7.4.1-1	NAC-STC with Redwood Impact Limiters	2.6.7.4-22
Figure 2.6.7.4.1-2	Cross Section of Redwood Impact Limiter	2.6.7.4-23
Figure 2.6.7.4.1-3	Crush Stress-Strain Curves for Redwood (Crush Strength Parallel to Grain)	2.6.7.4-24
Figure 2.6.7.4.1-4	Crush Stress-Strain Curves for Redwood (Crush Strength Perpendicular to Grain)	2.6.7.4-25
Figure 2.6.7.4.1-5	Crush Stress-Strain Curves for Balsa Wood (Crush Strength Parallel to Grain)	2.6.7.4-26
Figure 2.6.7.4.1-6	Variation of Crush Strength of Redwood and Balsa Wood with Impact Angle at 40 Percent Strain	2.6.7.4-27
Figure 2.6.7.4.1-7	Redwood Impact Limiter Attachment Geometry	2.6.7.4-28
Figure 2.6.7.4.1-8	Anchorage Detail of the Retaining Rod at the End of the Impact Limiter	2.6.7.4-29

List of Figures (Continued)

Figure 2.6.7.4.1-9	RBCUBED Output Summary - Center of Gravity Over Top Corner	2.6.7.4-30
Figure 2.6.7.4.1-10	Free Body Diagram - Upper Impact Limiter - Center of Gravity Over Corner	2.6.7.4-31
Figure 2.6.7.4.1-11	Free Body Diagram - Upper Impact Limiter - Cask Wedging Forces	2.6.7.4-32
Figure 2.6.7.4.2-1	Three-Dimensional View of the Balsa Impact Limiter	2.6.7.4-48
Figure 2.6.7.4.2-2	Cross-Sectional View of the Balsa Impact Limiter	2.6.7.4-49
Figure 2.6.7.4.2-3	LS-DYNA Model of the Balsa Impact Limiter	2.6.7.4-50
Figure 2.6.7.4.2-4	Balsa Impact Limiter Drop Orientation	2.6.7.4-51
Figure 2.6.7.4.2-5	Acceleration Time-History for 1-ft Side Drop on the Trunnion (Cold Conditions)	2.6.7.4-52
Figure 2.6.7.4.2-6	Acceleration Time-History for 1-ft End Drop (Cold Conditions)	2.6.7.4-53
Figure 2.6.7.4.2-7	Acceleration Time-History for 1-ft Drop onto Corner (Cold Conditions)	2.6.7.4-54
Figure 2.6.7.4.2-8	Acceleration Time-History for 30-ft Side Drop (Hot and Cold Conditions)	2.6.7.4-55
Figure 2.6.7.4.2-9	Acceleration Time-History for 30-ft End Drop (Hot and Cold Conditions)	2.6.7.4-56
Figure 2.6.7.4.2-10	Acceleration Time-History for 30-ft Drop onto Corner (Hot and Cold Conditions)	2.6.7.4-57
Figure 2.6.7.6-1	Neutron Shield Shell Geometry	2.6.7.6-12
Figure 2.6.10.2-1	Flow Diagram of the Plastic Analysis of Neutron Shield Shell	2.6.10.2-3
Figure 2.6.10.3-1	Port Cover Geometry and Loading	2.6.10.3-5
Figure 2.6.10.3-2	Finite Element Model of Port Cover	2.6.10.3-6
Figure 2.6.10.3-3	Port Cover Response to Penetration Event	2.6.10.3-7
Figure 2.6.12-1	NAC-STC PWR Fuel Assembly Basket for Directly Loaded Fuel	2.6.12-3
Figure 2.6.12-2	Support Disk Cross-Section Configuration for Directly Loaded Fuel	2.6.12-4
Figure 2.6.12-3	Fuel Tube Configuration for Directly Loaded Fuel	2.6.12-5

List of Figures (Continued)

Figure 2.6.16.4-1 Locations of CY-MPC Support Disk Maximum $P_m + P_b$ Stresses, 1-Foot End Drop 2.6.16-24

Figure 2.6.16.5-1 Locations of Maximum $P_m + P_b + Q$ Stresses for CY-MPC Support Disk for a 1-Foot End Drop, T_{max} = 550°F and T_{min} = 325°F 2.6.16-27

Figure 2.6.16.7-1 Locations of CY-MPC Support Disk Maximum P_m Stresses, 1-Foot Side Drop, 38° Orientation 2.6.16-33

Figure 2.6.16.7-2 Locations of CY-MPC Support Disk Maximum $P_m + P_b$ Stresses, 1-Foot Side Drop, 38° Orientation 2.6.16-34

Figure 2.6.16.8-1 Locations of CY-MPC Support Disk Maximum P + Q Stresses, 1-Foot Side Drop, 38° Orientation 2.6.16-45

Figure 2.6.16.11-1 Finite Element Model of the CY-MPC Top Weldment Plate 2.6.16-53

Figure 2.6.16.11-2 Finite Element Model of the CY-MPC Bottom Weldment Plate .. 2.6.16-54

Figure 2.6.17-1 CY-MPC Reconfigured Fuel Assembly Tube Support Grid Finite Element Model 2.6.17-13

Figure 2.6.19-1 Yankee-MPC GTCC Basket Assembly 2.6.19-14

Figure 2.6.19-2 CY-MPC GTCC Basket Tube Array Weldment Finite Element Model 2.6.19-15

Figure 2.6.19-3 CY-MPC GTCC Tube Array Weldment Boundary Conditions (45° Impact Orientation) 2.6.19-16

Figure 2.6.19-4 CY-MPC GTCC Tube Array – Section Locations of Top Five $P_m + P_b$ Stresses for the 75° Basket of the 1-Foot Side Drop Orientation 2.6.19-17

Figure 2.6.19-5 CY-MPC GTCC Basket Shield Shell Assembly Finite Element Model 2.6.19-18

Figure 2.6.19-6 CY-MPC GTCC Basket Shield Shell Assembly Loading and Boundary Conditions (75° Impact Orientation Shown) – Side Drop 2.6.19-19

Figure 2.6.19-7 CY-MPC GTCC Shield Shell – Section Locations of Top Four $P_m + P_b$ Stresses 2.6.19-20

Figure 2.7.1.1-1 Location of Sections for CY-MPC Configuration Stress Evaluation 2.7.1.1-10

Figure 2.7.1.2-1 Location of Sections for NAC-STC Cask Body Stress Evaluation for CY-MPC 2.7.1.2-13

List of Figures (Continued)

Figure 2.7.1.6-1 Finite Element Model - Lid Assembly (Loading Condition 1 - 56.1g Top Impact) 2.7.1.6-9
Figure 2.7.1.6-2 Finite Element Model - Lid Assembly (Loading Condition 2 - Pin Puncture) 2.7.1.6-10
Figure 2.7.1.6-3 Finite Element Model - Lid Assembly (Loading Condition 3 - 56.1-g Top Impact of Cavity Contents Plus Internal Pressure) 2.7.1.6-11
Figure 2.7.2.1-1 NAC-STC Midpoint Section 2.7.2.1-5
Figure 2.7.2.2-1 Finite Element Model - Lid Assembly – Yankee-MPC Pin Puncture 2.7.2.2-5
Figure 2.7.2.2-2 Lid Assembly Finite Element Model – CY-MPC Pin Puncture 2.7.2.2-9
Figure 2.7.2.3-1 NAC-STC Bottom Design Configuration 2.7.2.3-6
Figure 2.7.2.4-1 Port Cover Geometry 2.7.2.4-6
Figure 2.7.2.4-2 Puncture of Cask at Port Cover Location (Free Body Diagram) 2.7.2.4-7
Figure 2.7.3.4-1 Bolt Stress - Thermal (Fire) Accident 2.7.3.4-2
Figure 2.7.8-1 NAC-STC Directly Loaded 26 PWR Fuel Assembly Basket 2.7.8-3
Figure 2.7.8-2 Support Disk Cross-Sectional Configuration for Directly Loaded Fuel Configuration 2.7.8-4
Figure 2.7.8.1-1 Support Disk Drop Orientations 2.7.8.1-11
Figure 2.7.8.1-2 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (0° Drop Orientation) 2.7.8.1-12
Figure 2.7.8.1-3 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (15° Drop Orientation) 2.7.8.1-13
Figure 2.7.8.1-4 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (30° Drop Orientation) 2.7.8.1-14
Figure 2.7.8.1-5 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (37° Drop Orientation) 2.7.8.1-15
Figure 2.7.8.1-6 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (45° Drop Orientation) 2.7.8.1-16
Figure 2.7.8.1-7 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (60° Drop Orientation) 2.7.8.1-17

List of Figures (Continued)

Figure 2.7.8.1-8 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (64° Drop Orientation) 2.7.8.1-18
Figure 2.7.8.1-9 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (75° Drop Orientation) 2.7.8.1-19
Figure 2.7.8.1-10 Locations of 20 Maximum Nodal SI Stresses - 55-g Side Drop Impact (90° Drop Orientation) 2.7.8.1-20
Figure 2.7.8.1-11 Finite Element Model for the Basket Support Disk End Drop 2.7.8.1-21
Figure 2.7.8.1-12 Locations of the 20 Maximum Nodal SI Stresses - 56.1-g End Drop 2.7.8.1-22
Figure 2.7.8.1-13 Node Point Locations for Basket Web Stress Summaries 2.7.8.1-23
Figure 2.7.8.3-1 Finite Element Model of a Support Disk 2.7.8.3-13
Figure 2.7.8.4-1 Fuel Tube Configuration 2.7.8.4-6
Figure 2.7.8.4-2 Fuel Tube Finite Element Model Grid Loading 2.7.8.4-7
Figure 2.7.8.4-3 Fuel Tube Finite Model Distributed Pressure Loading 2.7.8.4-8
Figure 2.7.8.4-4 Elastic-Plastic Stress Distribution 2.7.8.4-9
Figure 2.7.9-1 Yankee-MPC Fuel Basket Assembly 2.7.9-3
Figure 2.7.9.1-1 Cask Orientation 2.7.9-5
Figure 2.7.9.4-1 Yankee-MPC Fuel Tube Configuration 2.7.9-31
Figure 2.7.9.5-1 Yankee-MPC Top Weldment Finite Element Model with Structural Boundary Conditions 2.7.9-33
Figure 2.7.9.5-2 Yankee-MPC Top Weldment Finite Element Model with Structural Applied Loads 2.7.9-33
Figure 2.7.9.5-3 Yankee-MPC Bottom Weldment Finite Element Model with Structural Boundary Conditions 2.7.9-34
Figure 2.7.9.5-4 Yankee-MPC Bottom Weldment Finite Element Model with Structural Applied Conditions 2.7.9-34

Figure 2.7.11-1 Identification of the Sections for Evaluating the Linearized Stresses in the Canister 2.7.11-4
Figure 2.7.11.5-1 Two-Dimensional Axisymmetric Model of the Upper Section of the Yankee-MPC Canister 2.7.11-14
Figure 2.7.11.5-2 Axial Acceleration (g) Time History for a Top End Impact, Yankee-MPC Canister 2.7.11-15

List of Figures (Continued)

Figure 2.7.11.5-3 Time History for the Ratio of the Dynamic Stress to the Static Stress (SDLF) for the Yankee-MPC Canister Structural Lid Weld (Nominal Gap Stiffness Value) 2.7.11-16
Figure 2.7.12-1 Identification of the Sections for Evaluating the Linearized Stresses in the CY-MPC Canister 2.7.12-6
Figure 2.7.13-1 CY-MPC Canistered Fuel Basket 2.7.13-3
Figure 2.7.13-2 CY-MPC Support Disk Configuration 2.7.13-4
Figure 2.7.13.1-1 Basket Drop Orientations 2.7.13.1-2
Figure 2.7.13.1-2 Cask Orientation 2.7.13.1-3
Figure 2.7.13.4-1 CY-MPC Fuel Tube Finite Element Model 2.7.13.4-6
Figure 2.7.13.4-2 CY-MPC Fuel Tube Analysis Results – Total Equivalent Strain (Uniform Loading) 2.7.13.4-7
Figure 2.7.13.4-3 CY-MPC Fuel Tube Analysis Results – Total Equivalent Strain (Grid Loading) 2.7.13.4-8
Figure 2.7.13.5-1 Finite Element Model of CY-MPC the Top Weldment 2.7.13.5-2
Figure 2.7.13.5-2 Finite Element Model of the CY-MPC Bottom Weldment 2.7.13.5-2
Figure 2.7.14-1 CY-MPC Reconfigured Fuel Assembly Tube Support Grid Finite Element Model 2.7.14-13
Figure 2.9.1-1 Two-Dimensional Beam Finite Element Model of the PWR 17 by 17 Fuel Rod 2.9-5
Figure 2.9.1-2 Mode Shape and First Buckling Shape for the PWR 17 by 17 Fuel Rod 2.9-6
Figure 2.9.2-1 First Buckling Mode for the Yankee Class Canistered Fuel 2.9-9
Figure 2.10.2-1 ANSYS Two-Dimensional Finite Element Model - NAC-STC 2.10.2-36
Figure 2.10.2-2 Cask Bottom (Region A) - NAC-STC ANSYS Two-Dimensional Model 2.10.2-37
Figure 2.10.2-3 Cask Lower Transition (Region B) - NAC-STC ANSYS Two-Dimensional Model 2.10.2-38
Figure 2.10.2-4 Cask Shells (Region C) - NAC-STC ANSYS Two-Dimensional Model 2.10.2-39
Figure 2.10.2-5 Cask Upper Transition (Region D) - NAC-STC ANSYS Two-Dimensional Model 2.10.2-40
Figure 2.10.2-6 Cask Top Forging (Region E) - NAC-STC ANSYS Two-Dimensional Model 2.10.2-41

List of Figures (Continued)

Figure 2.10.2-7 Cask Lids (Region F) - NAC-STC ANSYS Two-Dimensional Model 2.10.2-42
Figure 2.10.2-8 Circumferential Mesh Spacing (End View) - ANSYS Three-Dimensional Top and Bottom Fine Mesh Models 2.10.2-43
Figure 2.10.2-9 ANSYS Three-Dimensional Bottom Fine Mesh Finite Element Model - NAC-STC 2.10.2-44
Figure 2.10.2-10 Details - NAC-STC ANSYS Three-Dimensional Bottom Fine Mesh Model 2.10.2-45
Figure 2.10.2-11 Cask Bottom (Region A) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-46
Figure 2.10.2-12 Cask Bottom (Region B) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-47
Figure 2.10.2-13 Cask Bottom (Region C) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-48
Figure 2.10.2-14 Cask Lower Transition (Region D) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-49
Figure 2.10.2-15 Cask Lower Transition (Region E) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-50
Figure 2.10.2-16 Cask Lower Shell (Region F) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-51
Figure 2.10.2-17 Cask Lower Shell (Region G) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-52
Figure 2.10.2-18 Cask Upper Shell (Region H) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-53
Figure 2.10.2-19 Cask Lids (Region I) - NAC-STC ANSYS Bottom Fine Mesh Three-Dimensional Model 2.10.2-54
Figure 2.10.2-20 ANSYS Three-Dimensional Top Fine Mesh Finite Element Model - NAC-STC 2.10.2-55
Figure 2.10.2-21 Upper Half of NAC-STC ANSYS Three-Dimensional Top Fine Mesh Finite Element Model 2.10.2-56
Figure 2.10.2-22 Details - NAC-STC ANSYS Three-Dimensional Top Fine Mesh Model 2.10.2-57

List of Figures (Continued)

Figure 2.10.2-23 Cask Bottom (Region A) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-58
Figure 2.10.2-24 Cask Lower Transition (Region B) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-59
Figure 2.10.2-25 Cask Lower Shell (Region C) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-60
Figure 2.10.2-26 Cask Middle Shell (Region D) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-61
Figure 2.10.2-27 Cask Upper Shell (Region E) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-62
Figure 2.10.2-28 Cask Upper Transition (Region F) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-63
Figure 2.10.2-29 Cask Upper Transition (Region G) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-64
Figure 2.10.2-30 Cask Top Forging (Region H) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-65
Figure 2.10.2-31 Cask Lids (Region I) - NAC-STC ANSYS Top Fine Mesh Three-Dimensional Model 2.10.2-66
Figure 2.10.2-32 Load Distribution for Cask Side Drop Impact 2.10.2-67
Figure 2.10.2-33 ANSYS Finite Element Model - Structural Component Identification 2.10.2-68
Figure 2.10.2-34 ANSYS Finite Element Model - Representative Section Locations 2.10.2-69
Figure 2.10.2-35 Circular Nodal Locations - NAC-STC ANSYS Three-Dimensional Model 2.10.2-70
Figure 2.10.2-36 Nodal Identification - NAC-STC ANSYS Three-Dimensional Model 2.10.2-71
Figure 2.10.3.2-1 LS-DYNA Model used to Verify the Material Model 2.10.3-4
Figure 2.10.3.2-2 Stress-Strain Curve used for the Balsa Material 2.10.3-5
Figure 2.10.3.2-3 Finite Element Model for Strain-Rate Dependent Crushable Foam/Wood Block Impact 2.10.3-6
Figure 2.10.3.2-4 Stress Time History at 20 ε/sec 2.10.3-7
Figure 2.10.3.2-5 Stress Time History at 40 ε/sec 2.10.3-8

List of Figures (Continued)

Figure 2.10.6-1 Quarter-Scale Model Package Assembly - Ready for Cavity Pressure Test 2.10.6-43
Figure 2.10.6-2 Assembly of Cask - Inner Lid Fitted 2.10.6-44
Figure 2.10.6-3 Assembly of Cask - Fuel Pin Assemblies Located in Basket 2.10.6-45
Figure 2.10.6-4 Top End Drop - Cask Penetration into Impact Limiter 2.10.6-46
Figure 2.10.6-5 Side Drop - Detail of Shield Block Impact Near Bottom End 2.10.6-47
Figure 2.10.6-6 Repairs to Cask - 50 Metric Ton Hydraulic Press 2.10.6-48
Figure 2.10.6-7 Repairs to Cask - Local Over Pressing 2.10.6-49
Figure 2.10.6-8 Detail of Distortion to Basket Disk No. 6 - Side Drop 2.10.6-50
Figure 2.10.6-9 Deformation of Upper Impact Limiter - Top Corner Drop 2.10.6-51
Figure 2.10.6-10 Cask Midpoint Pin Puncture - Outer Shell Deformation 2.10.6-52
Figure 2.10.6-11 Center of Outer Lid Pin Puncture - Distortion of Punch 2.10.6-53
Figure 2.10.6-12 Quasi-Static Force-Deflection Curve, Eighth-Scale Model Impact Limiter - End (0-Degree) Impact 2.10.6-54
Figure 2.10.6-13 Quasi-Static Force-Deflection Curve, Eighth-Scale Model Impact Limiter - Corner (24-Degree) Impact 2.10.6-55
Figure 2.10.6-14 Force-Deformation Curve, Eighth-Scale Model Impact Limiter - Side (90-Degree) Impact 2.10.6-56
Figure 2.10.6-15 Location of Cask Body Metrology Measurements - Quarter-Scale Model 2.10.6-57
Figure 2.10.6-16 Location of Basket Support Disk Metrology Measurements - Quarter Scale Model 2.10.6-58
Figure 2.10.6-17 Strain Gauge Locations - Quarter-Scale Model 2.10.6-59
Figure 2.10.6-18 Accelerometer Locations - Quarter-Scale Model 2.10.6-60
Figure 2.10.6-19 Top End Drop (Test No. 1 of Phase 1) - Upper Impact Limiter Deformation (Using Impact Limiters With Aluminum Shells) 2.10.6-61
Figure 2.10.6-20 Top End Drop (Test No. 1 of Phase 1) Strain Data - Gauge S9.1 (Axial) (Using Impact Limiters With Aluminum Shells) 2.10.6-62
Figure 2.10.6-21 Top End Drop (Test No. 1 of Phase 1) Strain Data - Gauge S9.2 (Hoop) (Using Impact Limiters With Aluminum Shells) 2.10.6-63

List of Figures (Continued)

Figure 2.10.6-22 Top End Drop (Test No. 1 of Phase 1) Accelerometer Data - A2 (1 kHz Filter) (Using Impact Limiters With Aluminum Shells) 2.10.6-64
Figure 2.10.6-23 Side Drop Test (Test No. 3 of Phase 1) Accelerometer Data - A2 (Using Impact Limiters With Aluminum Shells) 2.10.6-65
Figure 2.10.6-24 Side Drop Test (Test No. 3 of Phase 1) - Deformation of Support Disk No. 6 (Using Impact Limiters With Aluminum Shells) 2.10.6-66
Figure 2.10.6-25 Top Corner Drop Test (Test No. 3 of Phase 3) - Impact Limiter Deformations 2.10.6-67
Figure 2.10.6-26 Top Corner Drop Test (Test No. 3 of Phase 3) Accelerometer Data - A1 ..... 2.10.6-68
Figure 2.10.6-27 Bottom Oblique Drop Test (Test No. 1 of Phase 4) - Distorted Area of Upper Impact Limiter 2.10.6-69
Figure 2.10.6-28 Bottom Oblique Drop Test (Test No. 1 of Phase 4) - Impact Limiter Deformations 2.10.6-70
Figure 2.10.6-29 Bottom Oblique Drop Test (Test No. 1 of Phase 4) - Impact Limiter Attachment Rods Post-Test Condition 2.10.6-71
Figure 2.10.6-30 Bottom Oblique Drop Test (Test No. 1 of Phase 4) Strain Data - Gauge S9.1 (Axial) 2.10.6-72
Figure 2.10.6-31 Bottom Oblique Drop Test (Test No. 1 of Phase 4) Strain Data - Gauge S9.2 (Hoop) 2.10.6-73
Figure 2.10.6-32 Bottom Oblique Drop Test (Test No. 1 of Phase 4) Accelerometer Data - A1 (750 Hz Filter) 2.10.6-74
Figure 2.10.6-33 Bottom Oblique Drop Test (Test No. 1 of Phase 4) Accelerometer Data - A2 (750 Hz Filter) 2.10.6-75
Figure 2.10.6-34 Side Drop Test (Test No. 2 of Phase 4) - Package Immediately After the Drop Test 2.10.6-76
Figure 2.10.6-35 Side Drop Test (Test No. 2 of Phase 4) - Deformed Base Impact Limiter After Removal 2.10.6-77
Figure 2.10.6-36 Side Drop Test (Test No. 2 of Phase 4) - Impact Limiter Deformations 2.10.6-78
Figure 2.10.6-37 Side Drop Test (Test No. 2 of Phase 4) Strain Data - Gauge S9.1 (Axial) 2.10.6-79

List of Figures (Continued)

Figure 2.10.6-38 Side Drop Test (Test No. 2 of Phase 4) Strain Data - Gauge S9.2 (Hoop) 2.10.6-80
Figure 2.10.6-39 Side Drop Test (Test No. 2 of Phase 4) Accelerometer Data -A1 (1 kHz Filter) 2.10.6-81
Figure 2.10.6-40 Side Drop Test (Test No. 2 of Phase 4) Accelerometer Data -A2 (750 Hz Filter) 2.10.6-82
Figure 2.10.7-1 Side Drop 2.10.7-14
Figure 2.10.7-2 End Drop 2.10.7-15
Figure 2.10.7-3 Oblique Drop 2.10.7-16
Figure 2.10.7-4 Cask Slapdown Geometry 2.10.7-17
Figure 2.10.7-5 Force-Deformation Curve - Lower Redwood Impact Limiter (Bottom End Impact, 0 Degrees) 2.10.7-18
Figure 2.10.7-6 Force-Deformation Curve - Lower Redwood Impact Limiter (Bottom Corner Impact, 24 Degrees) 2.10.7-19
Figure 2.10.7-7 Force-Deformation Curve - Lower Redwood Impact Limiter (Bottom Oblique Impact, 75 Degrees) 2.10.7-20
Figure 2.10.7-8 Force-Deformation Curve - Upper Redwood Impact Limiter (Top End Impact, 0 Degrees) 2.10.7-21
Figure 2.10.7-9 Force-Deformation Curve - Upper Redwood Impact Limiter (Top Corner Impact, 24 Degrees) 2.10.7-22
Figure 2.10.7-10 Force-Deformation Curve - Upper Redwood Impact Limiter (Top Oblique Impact, 75 Degrees) 2.10.7-23
Figure 2.10.7-11 Redwood Impact Limiter Force-Deformation Curve - Side Impact (90 Degrees) 2.10.7-24
Figure 2.10.9-1 Lead Slump - Cask 2D Model Element Plot 2.10.9-6
Figure 2.10.9-2 Lead Slump - Gap Element Plot 2.10.9-7
Figure 2.10.9-3 Lead Slump Displacement 2.10.9-8
Figure 2.10.9-4 Location of Node Points Used in Stress Summary 2.10.9-9
Figure 2.10.10-1 Identification Applicable to Temperature Summary 2.10.10-8
Figure 2.10.10-2 Component Wall Gradient Locations 2.10.10-9
Figure 2.10.11-1 Yankee-MPC Fuel Basket Drop Orientation 2.10.11-5
Figure 2.10.11-2 ANSYS Model for the Yankee-MPC Fuel Basket Support Disk .. 2.10.11-6
Figure 2.10.11-3 ANSYS Model for the Yankee-MPC Support Disk (Detail) 2.10.11-7

List of Figures (Continued)

Figure 2.10.11-4 ANSYS Models for Yankee-MPC Support Disk Ligament Mesh 2.10.11-8
Figure 2.10.12-1 Typical Filtered Acceleration Time History for the Quarter-Scale Model Side Drop, Overlayed with the Unfiltered Data for the Top End of the Model 2.10.12-17
Figure 2.10.12-2 The FFT for the Unfiltered Accelerometer Time History in Figure 2.10.12-1 ..... 2.10.12-18
Figure 2.10.12-3 Typical Filtered Acceleration Time History for the Quarter-Scale Model Side Drop, Overlaid with the LS-DYNA Filtered Time History for the Top End of the Model 2.10.12-19
Figure 2.10.12-4 Typical Filtered Acceleration Time History for the Quarter-Scale Model Side Drop, Overlaid with the LS-DYNA Filtered Time History for the Bottom End of the Model 2.10.12-20
Figure 2.10.12-5 Force Deflection Curve for the 30-Foot Side Drop Test 2.10.12-21
Figure 2.10.12-6 Typical Unfiltered Acceleration (Top Accelerometer) Time History for the Quarter-Scale Model Top Corner Drop 2.10.12-22
Figure 2.10.12-7 Typical Filtered Acceleration (Top Accelerometer) Time History for the Quarter-Scale Model Top Corner Side Drop 2.10.12-23
Figure 2.10.12-8 Comparison of Quarter-Scale Top Corner Drop (LS-DYNA and Drop Test) Results (Upper Accelerometer) 2.10.12-24
Figure 2.10.12-9 Force Deflection Curve for the Top Corner Drop 2.10.12-25
Figure 2.10.12-10 Typical Unfiltered Acceleration (Top Accelerometer) Time History for the Quarter-Scale Model Top End Drop 2.10.12-26
Figure 2.10.12-11 The FFT for the Unfiltered Accelerometer Time History in Figure 2.10.12-10 ..... 2.10.12-27
Figure 2.10.12-12 Typical Filtered Acceleration (Top Accelerometer) Time History for the Quarter-Scale Model Top End Drop 2.10.12-28
Figure 2.10.12-13 Comparison of Quarter-Scale Top End Drop (LS-DYNA and Drop Test) Results (Upper Accelerometer) 2.10.12-29
Figure 2.10.12-14 Force Deflection Curve for the Top End Drop 2.10.12-30
Figure 2.10.12-15 LS-DYNA Quarter-Scale Model 2.10.12-31

List of Tables

Table 2.1.2-1	Allowable Stress Limits for Containment Structures	2.1.2-4
Table 2.1.2-2	Allowable Stress Limits for Noncontainment Structures	2.1.2-5
Table 2.2-1	NAC-STC Calculated Weights and Centers of Gravity for Directly Loaded Fuel	2.2-3
Table 2.2-2	NAC-STC Calculated Weights and Centers of Gravity for Yankee-MPC Canistered Fuel	2.2-4
Table 2.2-3	NAC-STC Calculated Weights and Centers of Gravity for Canistered Yankee-MPC GTCC Waste	2.2-5
Table 2.2-4	NAC-STC Calculated Weights and Centers of Gravity for CY-MPC Canistered Fuel	2.2-6
Table 2.2-5	NAC-STC Calculated Weights and Centers of Gravity for Canistered CY-MPC GTCC Waste	2.2-7
Table 2.3.2-1	Mechanical Properties of SA 240, Type 304 Stainless Steel	2.3.2-2
Table 2.3.2-2	Mechanical Properties of SA 336, Type 304 Stainless Steel	2.3.2-3
Table 2.3.2-3	Mechanical Properties of Type XM-19 Stainless Steel	2.3.2-4
Table 2.3.2-4	Mechanical Properties of SA-240, Type 304L Stainless Steel	2.3.2-5
Table 2.3.3-1	Mechanical Properties of SA-705, SA-693 and SA-564, Type 630, H1150, 17-4 PH Stainless Steel	2.3.3-2
Table 2.3.4-1	Mechanical Properties of SB-637, Grade N07718 Nickel Alloy Steel Bolting Material	2.3.4-2
Table 2.3.4-2	Mechanical Properties of SA-193, Grade B6, High Alloy Steel Bolting Material	2.3.4-3
Table 2.3.5-1	Mechanical Properties of 6061-T651 and 6061-T6 Aluminum Alloy	2.3.5-2
Table 2.3.6-1	Static Mechanical Properties of Chemical Copper Lead	2.3.6-4
Table 2.3.6-2	Mechanical Properties of NS-4-FR	2.3.6-5
Table 2.4-1	Summary of NAC-STC Materials Categories and Operating Environments	2.4.4-10
Table 2.5.2-1	Reactions Caused By Tiedown Devices From 10 CFR 71.45(b) Loads	2.5.2-28
Table 2.5.2-2	Reactions Caused By Tiedown Devices from AAR Field Manual, Rule 88 Loads	2.5.2-29
Table 2.6.7.1-1	Section Locations for Stress Evaluation (Maximums)	2.6.7.1-13
Table 2.6.7.1-2	CY-MPC Critical P_m Stress Summary, 1-ft Top End Drop	2.6.7.1-14

List of Tables (Continued)

Table 2.6.7.1-3	CY-MPC Critical $P_m + P_b$ Stress Summary, 1-ft Top End Drop	2.6.7.1-15
Table 2.6.7.1-4	CY-MPC Critical P_m Stress Summary, 1-ft Bottom End Drop	2.6.7.1-16
Table 2.6.7.1-5	CY-MPC Critical $P_m + P_b$ Stress Summary, 1-ft Bottom End Drop	2.6.7.1-17
Table 2.6.7.2-1	Yankee-MPC Critical P_m Stress Summary; 1-ft. Side Drop; Drop Orientation = 90° (ksi)	2.6.7.2-18
Table 2.6.7.2-2	Yankee-MPC Critical $P_m + P_b$ Stress Summary; 1-ft. Side Drop; Drop Orientation = 90° (ksi)	2.6.7.2-18
Table 2.6.7.2-3	CY-MPC Critical P_m Stress Summary, 1-ft Side Drop	2.6.7.2-19
Table 2.6.7.2-4	CY-MPC Critical $P_m + P_b$ Stress Summary, 1-ft Side Drop	2.6.7.2-19
Table 2.6.7.4.1-1	Summary of Results - Impact Limiter Analysis for 1-Foot Free Drop	2.6.7.4-33
Table 2.6.7.4.1-2	Summary of Results - Impact Limiter Analysis for 30-Foot Free Drop	2.6.7.4-35
Table 2.6.7.4.1-3	Summary of Cask Drop Equivalent G-Load Factors	2.6.7.4-37
Table 2.6.7.4.1-4	Summary of 30-Foot Cask Drop Deceleration G-Loads for the Redwood Impact Limiter Obtained from RBCUBED, Tests, and Design	2.6.7.4-38
Table 2.6.7.4.2-1	Redwood Stress-Strain Properties	2.6.7.4-58
Table 2.6.7.4.2-2	Balsa Wood Stress-Strain Properties	2.6.7.4-58
Table 2.6.7.4.2-3	Summary of Results for the Balsa Impact Limiter Normal Conditions of Transport Drop Analysis	2.6.7.4-59
Table 2.6.7.4.2-4	Summary of Results for the Balsa Impact Limiter Hypothetical Accident Conditions Drop Analysis	2.6.7.4-59
Table 2.6.7.5-1	NAC-STC "Hot" Inner Lid Bolt Analysis (Normal Conditions of Transport)	2.6.7.5-11
Table 2.6.7.5-2	NAC-STC "Cold" Inner Lid Bolt Analysis (Normal Conditions of Transport)	2.6.7.5-12
Table 2.6.7.5-3	NAC-STC "Hot and Cold" Outer Lid Bolt Analysis (Normal Conditions of Transport)	2.6.7.5-13
Table 2.6.7.6-1	Neutron Shield Expansion Foam - Manufacturer's Force Deflection Data	2.6.7.6-13
Table 2.6.7.7-1	Resultant Stress Intensity Values in the Equivalent Ring	2.6.7.7-5

List of Tables (Continued)

Table 2.6.10.2-1 Stress Iteration Table for the Penetration Analysis of the Neutron Shield Shell (13-Pound Cylinder Drop From a 40-Inch Height) 2.6.10.2-4

Table 2.6.12.3-1 Thermal Stresses (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.3-7

Table 2.6.12.4-1 Stresses for 1-Foot End Drop Impact with a 19.6-g Deceleration (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.4-3

Table 2.6.12.5-1 Combined Stresses for Thermal + 19.6-g End Drop Impact (Directly Loaded Fuel Configuration - Support Disk) 2.6.12.5-3

Table 2.6.12.7-1 18.1-g Side Impact Stresses for 0-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-13

Table 2.6.12.7-2 18.1-g Side Impact Stresses for 15-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-14

Table 2.6.12.7-3 18.1-g Side Impact Stresses for 30-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-15

Table 2.6.12.7-4 18.1-g Side Impact Stresses for 37-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-16

Table 2.6.12.7-5 18.1-g Side Impact Stresses for 45-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-17

Table 2.6.12.7-6 18.1-g Side Impact Stresses for 60-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-18

Table 2.6.12.7-7 18.1-g Side Impact Stresses for 64-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-19

Table 2.6.12.7-8 18.1-g Side Impact Stresses for 75-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-20

List of Tables (Continued)

Table 2.6.12.7-9 18.1-g Side Impact Stresses for 90-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-21
Table 2.6.12.7-10 18.1-g Side Impact Analysis Results (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.7-22
Table 2.6.12.9-1 18.1-g Side Impact Web Stresses for 0-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-3
Table 2.6.12.9-2 18.1-g Side Impact Web Stresses for 15-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-4
Table 2.6.12.9-3 18.1-g Side Impact Web Stresses for 30-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-5
Table 2.6.12.9-4 18.1-g Side Impact Web Stresses for 37-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-6
Table 2.6.12.9-5 18.1-g Side Impact Web Stresses for 45-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-7
Table 2.6.12.9-6 18.1-g Side Impact Web Stresses for 60-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-8
Table 2.6.12.9-7 18.1-g Side Impact Web Stresses for 64-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-9
Table 2.6.12.9-8 18.1-g Side Impact Web Stresses for 75-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-10
Table 2.6.12.9-9 18.1-g Side Impact Web Stresses for 90-Degree Drop Orientation (NAC-STC PWR Basket - Directly Loaded Fuel Configuration) 2.6.12.9-11
Table 2.6.13.2-1 Real Constant Sets Defined in Yankee-MPC Canister Model 2.6.13.2-7
Table 2.6.13.2-2 Material Sets Defined in Yankee-MPC Canister Model 2.6.13.2-7

List of Tables (Continued)

Table 2.6.13.3-1 Linearized Stresses in the Yankee-MPC Canister - Thermal Only (Condition 2) 2.6.13.3-4
Table 2.6.13.4-1 Summary of Critical Sections of the Yankee-MPC Canister for the 1-Foot End Drop Condition 2.6.13.4-2
Table 2.6.13.4-2 Internal Pressure Only (20 psi) - Yankee-MPC Canister Primary Membrane Stresses (psi) 2.6.13.4-3
Table 2.6.13.4-3 Internal Pressure Only (20 psi) - Yankee-MPC Canister Primary Membrane Plus Primary Bending Stresses (psi) 2.6.13.4-3
Table 2.6.13.4-4 Top End Drop: 1-ft. Drop + Internal Pressure (20 psi) - Yankee-MPC Canister Primary Membrane Stresses (psi) 2.6.13.4-4
Table 2.6.13.4-5 Top End Drop: 1-ft. Drop + Internal Pressure (20 psi) - Yankee-MPC Canister Primary Membrane Plus Primary Bending Stresses (psi) 2.6. 13.4-4
Table 2.6.13.4-6 Bottom End Drop: 1-ft. Drop + Internal Pressure (0 psi) - Yankee-MPC Canister Primary Membrane Stresses (psi) 2.6.13.4-5
Table 2.6.13.4-7 Bottom End Drop: 1-ft. Drop + Internal Pressure (0 psi) - Yankee-MPC Canister Primary Membrane Plus Primary Bending Stresses (psi) 2.6.13.4-5
Table 2.6.13.5-1 Yankee-MPC Canister Bottom End Drop: 1-ft. Drop + Internal Pressure (0 psi) + Thermal (cold) (psi) 2.6.13.5-2
Table 2.6.13.5-2 Yankee-MPC Canister Top End Drop: 1-ft. Drop + Internal Pressure (20 psi) + Thermal (cold) (psi) 2.6.13.5-2
Table 2.6.13.6-1 Yankee-MPC Canister Side Drop: 1-ft. Drop + Internal Pressure (20 psi) - Primary Membrane Stresses (psi) 2.6.13.6-2
Table 2.6.13.6-2 Yankee-MPC Canister Side Drop: 1-ft. Drop + Internal Pressure (20 psi) - Primary Membrane Plus Primary Bending Stresses (psi) 2.6.13.6-2
Table 2.6.13.7-1 Yankee-MPC Canister Side Drop: 1-ft. Drop + Internal Pressure (20 psi) + Thermal (cold) (psi) 2.6.13.7-2
Table 2.6.14.2-1 Listing of Cross Sections for Stress Evaluation of Yankee-MPC Basket Support Disk (0° Basket Drop Orientation) 2.6.14-17
Table 2.6.14.2-2 Listing of Cross Sections for Stress Evaluation of Yankee-MPC Support Disk (45° Basket Drop Orientation) 2.6.14-21

List of Tables (Continued)

Table 2.6.14.4-1 $P_m + P_b$ Stresses for Yankee-MPC Basket Support Disk—1-Foot End Drop Thermal Condition 2 ..... 2.6.14-29

Table 2.6.14.4-2 $P_m + P_b$ Stresses for Yankee-MPC Basket Support Disk—1-Foot End Drop Thermal Condition 3 ..... 2.6.14-30

Table 2.6.14.5-1 P + Q Stresses for Yankee-MPC Basket Support Disk—1-Foot End Drop Thermal Condition 2 ..... 2.6.14-33

Table 2.6.14.7-1 Summary of Maximum Yankee-MPC Basket Support Disk Stresses for 1-Foot Side Drop 2.6.14-40

Table 2.6.14.7-2 P_m Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 0° Basket Orientation, Thermal Condition 2, Disk Number 1 ..... 2.6.14-41

Table 2.6.14.7-3 $P_m + P_b$ Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 0° Basket Orientation, Thermal Condition 2, Disk Number 1 ..... 2.6.14-42

Table 2.6.14.7-4 P_m Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 0° Basket Orientation, Thermal Condition 3, Disk Number 1 ..... 2.6.14-43

Table 2.6.14.7-5 $P_m + P_b$ Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 0° Basket Orientation, Thermal Condition 3, Disk Number 1 ..... 2.6.14-44

Table 2.6.14.7-6 P_m Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 45° Basket Orientation, Thermal Condition 2, Disk Number 5 ..... 2.6.14-45

Table 2.6.14.7-7 $P_m + P_b$ Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 45° Basket Orientation, Thermal Condition 2, Disk Number 5 ..... 2.6.14-46

Table 2.6.14.7-8 P_m Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 45° Basket Orientation, Thermal Condition 3, Disk Number 5 ..... 2.6.14-47

Table 2.6.14.7-9 $P_m + P_b$ Stresses for Yankee-MPC Basket Support Disk—1- Foot Side Drop, 45° Basket Orientation, Thermal Condition 3, Disk Number 5 ..... 2.6.14-48

Table 2.6.14.8-1 Summary of Maximum Yankee-MPC Basket Support Disk Stresses for Thermal Plus 1-Foot Side Drop 2.6.14-52

List of Tables (Continued)

Table 2.6.14.8-2 P + Q Stresses for Yankee-MPC Basket Support Disk—1-Foot Side Drop, 0° Basket Orientation, Thermal Condition 2, Disk Number 1 ..... 2.6.14-53

Table 2.6.14.8-3 P + Q Stresses for Yankee-MPC Basket Support Disk—1 Foot Side Drop, 45° Basket Orientation, Thermal Condition 2, Disk Number 5 ..... 2.6.14-54

Table 2.6.14.11-1 Minimum Margins of Safety for the Yankee-MPC Fuel Basket Top/Bottom Weldments for a 1-Foot End Drop With and Without Thermal Stresses 2.6.14-59

Table 2.6.15.2-1 Real Constant Sets Defined in CY-MPC Canister Model 2.6.15.2-7

Table 2.6.15.2-2 Material Sets Defined in CY-MPC Canister Model 2.6.15.2-7

Table 2.6.15.3-1 CY-MPC Linearized Stresses – Thermal Only (Condition 2) 2.6.15.3-4

Table 2.6.15.4-1 Summary of Critical Sections of the Canister for the 1-Foot End Drop Condition 2.6.15.4-2

Table 2.6.15.4-2 Internal Pressure Only (20 psi) – Primary Membrane Stresses (ksi) 2.6.15.4-3

Table 2.6.15.4-3 Internal Pressure Only (20 psi) – Primary Membrane Plus Primary Bending Stresses (ksi) 2.6.15.4-3

Table 2.6.15.4-4 Top End Drop: 1-ft Drop + Internal Pressure (20 psi) – Primary Membrane Stresses (ksi) 2.6.15.4-4

Table 2.6.15.4-5 Top End Drop: 1-ft Drop + Internal Pressure (20 psi) – Primary Membrane Plus Primary Bending Stresses (ksi) 2.6.15.4-4

Table 2.6.15.4-6 Bottom End Drop: 1-ft Drop + Internal Pressure (0 psi) – Primary Membrane Stresses (ksi) 2.6.15.4-5

Table 2.6.15.4-7 Bottom End Drop: 1-ft Drop + Internal Pressure (0 psi) – Primary Membrane Plus Primary Bending Stresses (ksi) 2.6.15.4-5

Table 2.6.15.6-1 Side Drop: 1-ft. Drop + Internal Pressure (20 psi) – Primary Membrane Stresses (ksi) 2.6.15.6-3

Table 2.6.15.6-2 Side Drop: 1-ft. Drop + Internal Pressure (20 psi) – Primary Membrane Plus Primary Bending Stresses (ksi) 2.6.15.6-3

Table 2.6.16.2-1 Cross Sections for Stress Evaluation of CY-MPC Support Disk .. 2.6.16-16

Table 2.6.16.4-1 $P_m + P_b$ Stresses for CY-MPC Support Disk, 1-Foot End Drop 2.6.16-25

List of Tables (Continued)

Table 2.6.16.5-1 P + Q Stresses for CY-MPC Support Disk – 1-Foot End Drop T_{max} = 550°F and T_{min} = 325°F 2.6.16-28
Table 2.6.16.7-1 Summary of Maximum CY-MPC Support Disk Stresses for 1-Foot Side Drop 2.6.16-35
Table 2.6.16.7-2 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 0° Basket Orientation 2.6.16-36
Table 2.6.16.7-3 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation 2.6.16-37
Table 2.6.16.7-4 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 63° Basket Orientation 2.6.16-38
Table 2.6.16.7-5 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 90° Basket Orientation 2.6.16-39
Table 2.6.16.7-6 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 0° Basket Orientation 2.6.16-40
Table 2.6.16.7-7 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation 2.6.16-41
Table 2.6.16.7-8 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 63° Basket Orientation 2.6.16-42
Table 2.6.16.7-9 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 90° Basket Orientation 2.6.16-43
Table 2.6.16.8-1 Summary of Maximum CY-MPC Support Disk P + Q Stresses for 1-Foot Side Drop 2.6.16-46
Table 2.6.16.8-2 P + Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 0° Basket Orientation 2.6.16-47
Table 2.6.16.8-3 P + Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation 2.6.16-48
Table 2.6.16.8-4 P + Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 63° Basket Orientation 2.6.16-49
Table 2.6.16.8-5 P + Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 90° Basket Orientation 2.6.16-50
Table 2.6.16.11-1 Minimum Margins of Safety for the CY-MPC Top/Bottom Weldments for a 1-Foot End Drop With and Without Thermal Stresses 2.6.16-55

List of Tables (Continued)

Table 2.6.16.12-1 NUREG/CR 6322 Buckling Analysis for the CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation 2.6.16-57

Table 2.6.19-1 CY-MPC GTCC Tube Array Weldment P_m Stress Summary – 75° Side Drop, Normal Condition 2.6.19-21

Table 2.6.19-2 CY-MPC GTCC Tube Array Weldment $P_m + P_b$ Stress Summary – 75° Side Drop, Normal Condition 2.6.19-21

Table 2.6.19-3 CY-MPC GTCC Tube Array Weld Evaluation - 75° Side Drop, Normal Condition 2.6.19-22

Table 2.6.19-4 CY-MPC GTCC Shield Shell Weldment P_m Stress Summary – 75° Side Drop, Normal Condition 2.6.19-23

Table 2.6.19-5 CY-MPC GTCC Shield Shell Weldment $P_m + P_b$ Stress Summary - 75° Side Drop, Normal Condition 2.6.19-23

Table 2.7.1.1-1 NAC-STC Section Locations for CY-MPC Stress Evaluation (Maximums) 2.7.1.1-11

Table 2.7.1.1-2 NAC-STC Critical P_m Stress Summary for CY-MPC: 30-ft Top End Drop 2.7.1.1-12

Table 2.7.1.1-3 NAC-STC Critical $P_m + P_b$ Stress Summary for CY-MPC: 30-ft Top End Drop 2.7.1.1-13

Table 2.7.1.1-4 NAC-STC Critical P_m Stress Summary for CY-MPC: 30-ft Bottom End Drop 2.7.1.1-14

Table 2.7.1.1-5 NAC-STC Critical $P_m + P_b$ Stress Summary for CY-MPC: 30-ft Bottom End Drop 2.7.1.1-15

Table 2.7.1.2-1 Yankee-MPC Critical P_m Stress Summary; 30-ft Side Drop; Drop Orientation = 90° 2.7.1.2-14

Table 2.7.1.2-2 Yankee-MPC Critical $P_m + P_b$ Stress Summary; 30-ft Side Drop; Drop Orientation = 90° 2.7.1.2-14

Table 2.7.1.2-3 CY-MPC Configuration Section Locations for Stress Evaluation (Maximums) 2.7.1.2-15

Table 2.7.1.2-4 CY-MPC Configuration Critical P_m Stress Summary: 30-ft Side Drop 2.7.1.2-15

Table 2.7.1.2-5 CY-MPC Configuration Critical $P_m + P_b$ Stress Summary: 30-ft Side Drop 2.7.1.2-16

Table 2.7.1.6-1 Stress Summary - Accident Analyses of the NAC-STC Inner and Outer Lids 2.7.1.6-12

List of Tables (Continued)

Table 2.7.1.6-2 NAC-STC "Hot" Inner Lid Bolt Analysis (Hypothetical Accident Condition) 2.7.1.6-14
Table 2.7.1.6-3 NAC-STC "Cold" Inner Lid Bolt Analysis (Hypothetical Accident Condition) 2.7.1.6-15
Table 2.7.1.6-4 NAC-STC "Hot and Cold" Outer Lid Bolt Analysis (Hypothetical Accident Condition) 2.7.1.6-16

Table 2.7.3.2-1 Cask Internal Pressure Stress Summary - Thermal Accident (125 psig) 2.7.3.2-3
Table 2.7.3.2-2 Canister Pressure Stress Summary - Thermal Accident (50 psig) (Primary Membrane Stress) 2.7.3.2-4
Table 2.7.3.2-3 Canister Pressure Stress Summary - Thermal Accident (50 psig) (Primary Membrane Stress + Bending Stress) 2.7.3.2-5
Table 2.7.7-1 Summary of Maximum Calculated Stresses - 30-Foot Free Drop 2.7.7-2
Table 2.7.7-2 Summary of Maximum Calculated Stresses - Puncture 2.7.7-3
Table 2.7.7-3 Summary of Maximum Calculated Stresses - Thermal (Fire) Accident 2.7.7-4
Table 2.7.8.1-1 Basket 55-g Side Impact Stresses for 0-Degree Drop Orientation 2.7.8.1-24
Table 2.7.8.1-2 Basket 55-g Side Impact Stresses for 15-Degree Drop Orientation 2.7.8.1-25
Table 2.7.8.1-3 Basket 55-g Side Impact Stresses for 30-Degree Drop Orientation 2.7.8.1-26
Table 2.7.8.1-4 Basket 55-g Side Impact Stresses for 37-Degree Drop Orientation 2.7.8.1-27
Table 2.7.8.1-5 Basket 55-g Side Impact Stresses for 45-Degree Drop Orientation 2.7.8.1-28
Table 2.7.8.1-6 Basket 55-g Side Impact Stresses for 60-Degree Drop Orientation 2.7.8.1-29
Table 2.7.8.1-7 Basket 55-g Side Impact Stresses for 64-Degree Drop Orientation 2.7.8.1-30

2.1 Structural Design

2.1.1 Discussion

The NAC-STC is a cylindrical, multiwall cask designed to safely transport directly loaded or canistered spent nuclear fuel or canistered Greater Than Class C (GTCC) waste. The cask accommodates up to 26 directly loaded design basis PWR fuel assemblies. In the canistered fuel or waste configurations, the NAC-STC transports the Multi-Purpose Canister (MPC) of the NAC-MPC system, which is designed for the long-term storage and transport of spent fuel. The NAC-MPC is provided in several configurations to provide efficient storage and transport of both spent fuel and GTCC waste. The NAC-MPC canister system designed for Yankee Class fuel is designated the Yankee-MPC and holds up to 36 Yankee Class fuel assemblies. Using a modified internal basket, the same size canister also holds up to 24 containers of Yankee GTCC waste. The NAC-MPC canister system designed for Connecticut Yankee is designated the CY-MPC and holds up to 26 Connecticut Yankee fuel assemblies or, using a modified internal basket, up to 24 containers of Connecticut Yankee GTCC waste. The Yankee-MPC and CY-MPC canisters have the same external diameter, but have different overall lengths. The CY-MPC canister system has a higher allowable contents weight than the directly loaded or Yankee-MPC system. To accommodate the higher contents weight, a balsa wood impact limiter is used with the CY-MPC configuration. The balsa wood impact limiter is referred to as the "balsa impact limiter." The balsa impact limiter has performance characteristics comparable to the redwood and balsa wood impact limiters ("redwood impact limiter"), but weighs significantly less. As noted in Section 2.2, the balsa impact limiters can be used with any NAC-STC configuration. However, the redwood impact limiters are used only with the directly loaded and Yankee-MPC configurations.

The primary components of the NAC-STC are: (1) the cask body—inner shell, outer shell, lead shell, and bottom; (2) the inner lid, bolts, and metallic o-rings; (3) the outer lid, bolts, and metallic o-ring; (4) the port covers, port coverplates, bolts, and o-rings; (5) the neutron shield; (6) the trunnions; (7) the transport impact limiters—upper and lower; and (8) the fuel basket. The NAC-STC primary containment boundary for storage and transport after storage consists of: (1) inner shell center section and upper and lower inner shell rings (transition sections); (2) bottom inner forging; (3) top forging; (4) inner lid and inner lid outer metallic o-ring; (5) inner lid interseal test port and its threaded plug with metallic o-ring; (6) vent port coverplate and vent port coverplate outer metallic o-ring; (7) vent port coverplate interseal test threaded plug with

metallic o-ring; (8) drain port coverplate and drain port coverplate outer metallic o-ring; and (9) drain port coverplate interseal test threaded plug with metallic o-ring. A detailed discussion of the containment boundary is presented in Chapter 4. As described in Section 7.1.3, for loading of the NAC-STC for immediate shipment, the containment boundary for the inner lid and drain port coverplate are the inner metallic o-rings, rather than the outer o-rings and interseal test plugs. The geometry and the materials of fabrication of the cask components are described in Section 1.2.1 and are shown on the license drawings presented in Section 1.3.2.

The NAC-STC is designed to satisfy the requirements of 10 CFR 71 for the transport of radioactive materials (and the requirements of 10 CFR 72 for the storage of radioactive materials) and the requirements of IAEA Safety Series No. 6. The cask body holds and protects the cask cavity contents for the normal conditions of transport, as well as for the hypothetical accident conditions. The lead located between the inner and outer shells provides the primary gamma radiation shielding for the cask in the radial direction. The cask bottom connects the inner and outer shells, providing for the bottom end closure, as well as both gamma and neutron radiation shielding in the axial direction.

The inner lid, bolts, and metallic o-rings are the primary closure components of the NAC-STC for transport conditions. The outer lid and metallic o-ring provide a secondary closure boundary.

The vent port and the drain port are located in the inner lid and are each protected by a port coverplate. The primary containment boundary at the vent port and at the drain port is the port coverplate and its outer metallic o-ring. The o-ring is located in the bottom surface of the port coverplate. A second metallic o-ring is also located in the bottom surface of the port coverplate, inside of, and concentric with, the primary containment, outer metallic o-ring. The seals of the metallic o-rings are tested by pressurizing the annulus between them with helium and using a "sniffer" probe to detect helium leakage at the outer circumference of the inner lid and port coverplates.

The forty-two 1 1/2 - 8 UN inner lid bolts are preloaded by an installation torque to restrain rotation of the edge of the inner lid and to maintain a containment seal for the critical load condition. This condition is a uniformly distributed pressure resulting from the impact of the basket and cavity contents on the inner surface during a top end or top corner impact. The critical design load condition for the inner lid bolts, as listed in Table 2.7.1.6-2, Section 2.7.1.6,

The allowable number of cycles associated with an $(SI)_a$ = 98.2 ksi is 2000 cycles. This number of allowable cycles considerably exceeds the number of normal operating cycles that the NAC-STC will incur during its lifetime.

2.1.3.2.2 Outer Lid

Using a similar method of evaluation for the outer lid (SA-705, Type 630, H1150, 17-4 PH stainless steel) at 200°F, conservatively high for stress concentration areas, S_m = 45.0 ksi (Table 2.3.3-1) and 3.0 S_m = 135.0 ksi. The maximum stress concentration in the outer lid occurs at the bolt hole locations. At the outer lid bolt hole locations, the bolt hole diameter is d = 1.0 inch and the bolt hole pitch is w = 7.30 inches (36 holes on a 83.70-inch bolt circle). Then, d/w = 0.137 and the stress concentration factor is k_t = 3.07 (Peterson, Figure 86). Using a stress concentration factor of 3.07, the maximum allowable peak stress intensity range is $(SI)_{pr}$ = (3.07)(135.0) = 414.5 ksi and the peak stress intensity amplitude is $(SI)_{pa} = (SI)_{pr}/2$ = 207.2 ksi. From the "ASME Boiler and Pressure Vessel Code," Section III, Appendix I, Figure I-9.2.1, the peak stress intensity amplitude is ratioed to incorporate the modulus of elasticity at 200°F, $(SI)_a$ = (207.2)(28.3/27.8) = 211.0 ksi. The allowable number of cycles associated with an $(SI)_a$ = 211.0 ksi is 190 cycles. Since this allowable number of cycles is excessively restrictive for the lifetime of a spent fuel transport cask, the grossly conservative evaluation methodology will be revised to use the maximum calculated stress in the outer lid. Since the maximum calculated stress in the outer lid is 19,647 psi (Table 2.7.1.6-1) for a 56.1 g, 30-foot drop top end impact accident load condition, it is very conservative to use this stress value in a normal operating condition fatigue analysis of the outer lid. The maximum peak stress intensity range for the outer lid is $(SI)_{pr}$ = (3.07)(19.6) = 60.2 ksi and the peak stress intensity amplitude is $(SI)_{pa} = (SI)_{pr}/2$ = 30.1 ksi. From the "ASME Boiler and Pressure Vessel Code," Section III, Appendix I, Figure I-9.2.1, the peak stress intensity amplitude is ratioed to incorporate the modulus of elasticity at 200°F, $(SI)_a$ = (30.1)(28.3/27.8) = 30.6 ksi. The allowable number of cycles associated with an $(SI)_a$ = 30.6 ksi is 90,000 cycles. This number of allowable cycles far exceeds the number of Normal Conditions of Transport loading cycles that the NAC-STC will incur during its lifetime of spent fuel transport.

2.1.3.2.3 Bolts

Stress concentration occurs in the inner lid bolts, the outer lid bolts, the port cover bolts, and the port coverplate bolts. The maximum cyclic stress in these bolts is due to the installation preload and thermally induced loads. From Shigley, the preload torque is calculated as:

$$T = \left[\left(\frac{d_m}{2d}\right)\left(\frac{\tan\lambda + \mu\sec\alpha}{1 - \mu\tan\lambda\sec\alpha}\right) + 0.625\mu\right](F)(d)$$

where:

F = preload force
d = bolt diameter
d_m = mean diameter of threads
α = one-half the thread angle
μ = coefficient of friction
$\tan\lambda = \frac{1}{\pi d_m N}$
N = number of threads per inch

2.1.3.2.3.1 Inner Lid Bolts

The maximum installation torque for each SB-637, Grade N07718 nickel alloy inner lid bolt is 2,740 foot-pounds (2,540 ± 200), or 32,880 inch-pounds; thus, T = 32,880 inch-pounds. The nominal inner lid bolt thread diameter is 1.5 inches; thus, d = 1.5 inches. Based on the evaluation in Section 2.6.7.5.4.1, the maximum normal tensile stress (preload + thermal) in each inner lid bolt is calculated as 86.3 ksi.

From the "ASME Boiler and Pressure Vessel Code," Section III, NB-3232.3(c), the fatigue strength reduction factor is assumed to be 4.0. In addition, the modulus of elasticity at 200°F is 28.3 x 10^6 psi (SB-637, Grade N07718 nickel alloy steel). Since the "ASME Boiler and Pressure Vessel Code," Section III, Figure I-9.4 is based on a modulus of elasticity of 30.0 x 10^6 psi, the equivalent stress range is:

S_{range} = (86,306)(4.0)(30.0 x 10^6/28.3 x 10^6)

= 365,962 psi

The alternating stress is one-half of the stress range, or S_a = 183,817 psi. Using Figure I-9.4, Section III, "ASME Boiler and Pressure Vessel Code," the allowable number of normal operating cycles is 301 cycles (one cycle consists of one application and removal of preload). Assuming a maximum of 12 cycles per year for the bolts, a 25.1-year life is projected. Operational procedures will specify replacement of an entire set of these bolts every 240 cycles (20 years), ensuring a fatigue failure margin of safety of + 0.26.

2.1.3.2.3.2 Outer Lid Bolts

The allowable number of normal operating cycles for the outer lid bolts is calculated similarly to that for the inner lid bolts.

The maximum installation torque (T) for an outer lid bolt is 600 foot-pounds, or 7,200 inch-pounds; thus, T = 7,200 inch-pounds. The nominal thread diameter of an outer lid bolt is 1.0 inch; thus, d = 1.0 inch. Based on the evaluation in Section 2.6.7.5.4.2, the maximum tensile stress in each outer lid bolt is calculated to be 60,743 psi.

Again, assuming a fatigue strength reduction factor of 4.0 and ratioing for the modulus of elasticity at 200°F, 27.6 x 10^6 psi (SA-564, Type 630, H1150, 17-4 PH stainless steel), the equivalent stress range is S_{range} = 264,100 psi. Then, the alternating stress is S_a =132,050 psi and the allowable number of normal operating cycles is 573 cycles (Figure I-9.1, Appendix I, "ASME Boiler and Pressure Vessel Code"), which is significantly greater than the 240 cycles of normal transport loads that the NAC-STC is expected to incur during its lifetime.

2.1.3.2.3.3 Port Cover Bolts

The allowable number of normal operating cycles for the port cover bolts is calculated similarly to that for the inner lid bolts. The installation torque for a bolt for the port cover is 140 inch-pounds; thus, T = 140 inch-pounds. The nominal thread diameter of a bolt for the port cover is 0.375 inch; thus, d = 0.375 inch. The calculated tensile force and stress in the port cover bolts are 1,875 pounds and 30,242 psi, respectively. Assuming a fatigue strength reduction factor of

4.0 and ratioing for the modulus of elasticity at 200°F, 28.5 x 10^6 psi (SA-193, Grade B6 High Alloy Steel Bolting Material), the equivalent stress range is S_{range} = 127,335 psi. Then, the alternating stress is S_a = 63,667 psi and the allowable number of normal operating cycles for the bolts for the port cover is 1650 cycles (Figure I-9.4, Appendix I, "ASME Boiler and Pressure Vessel Code"), which is greater than the 240 cycles of normal transport loads that the NAC-STC is expected to incur during its lifetime.

2.1.3.2.3.4 Port Coverplate Bolts

The allowable number of normal operating cycles for the port coverplate bolts is calculated similarly to that for the inner lid bolts. The installation torque for a port coverplate bolt is 300 inch-pounds; thus, T = 300 inch-pounds. The nominal thread diameter of a bolt for the port coverplate is 0.5 inch; thus, D = 0.50 inch. The calculated tensile force and stress in the port coverplate bolts are 4,110 pounds and 28,964 psi, respectively. Again, assuming a fatigue strength reduction factor of 4.0 and ratioing for the modulus of elasticity at 200°F, 28.5 x 10^6 psi (SA-193, Grade B6 High Alloy Steel Bolting Material), the equivalent stress range is S_{range} = 121,954 psi. Then, the alternating stress is S_a = 60,977 psi and the allowable number of normal operating cycles for the bolts for the port coverplate is 1,700 cycles (Figure I-9.4, Appendix I, "ASME Boiler and Pressure Vessel Code"), which is greater than the 240 cycles of normal transport loads that the NAC-STC is expected to incur during its lifetime.

2.1.3.2.4 Normal Over-the-Rail Vibration

Fatigue concerns associated with normal over-the-rail vibration are addressed in Section 2.6.5.

2.1.3.3 Extreme Total Stress Intensity Range

Paragraph C.7 of Regulatory Guide 7.6 defines the "low cycle" fatigue stress limit for any point in the containment vessel for the cask's entire life—initial state, fabrication state, normal transport conditions and hypothetical accident--as a limit on the maximum stress intensity range. That limit is equal to twice the allowable alternating stress at 10 cycles (S_a) as tabulated in the mechanical properties of materials, Section 2.3. S_a has been adjusted by the ratio of the material's modulus of elasticity (at the applicable temperature for the load combination being evaluated) to the modulus of elasticity used in the development of the material fatigue curve. At

2.3.7 Impact Limiter Materials

The transport impact limiters for the NAC-STC are fabricated in two configurations. The first configuration is the "redwood impact limiter," which is described in Section 2.6.7.4.1. The second configuration is the "balsa impact limiter," described in Section 2.6.7.4.2. The balsa impact limiter weighs significantly less than the redwood impact limiter. Both impact limiter configurations absorb the energy of a cask drop impact by crushing the redwood and/or balsa wood in the impact limiter.

The evaluation of the redwood impact limiter design employs the properties for redwood and balsa wood contained in Figures 2.6.7.4.1-3 through 2.6.7.4.1-5. These figures present the crush stress-strain curves for redwood and balsa wood materials.

The evaluation of the balsa impact limiter design employs the properties for redwood and balsa contained in Tables 2.6.7.4.2-1 and 2.6.7.4.2-2. These tables present the crush stress-strain data for redwood and balsa wood materials, respectively.

THIS PAGE INTENTIONALLY LEFT BLANK

2.3.8 Spacer Materials

Spacers are installed in the NAC-STC cask cavity for the transport of the Yankee-MPC and CY-MPC canisters containing either spent fuel or GTCC waste. The spacers are designed to locate the canister axially in the cavity so that the package center of gravity is located approximately in the same position as that of the directly loaded fuel configuration of the cask. Removable lifting lugs are used to install and remove the spacer.

Two spacers (top and bottom) are used in the transport of the Yankee-MPC. Both spacers are fabricated from aluminum honeycomb encased in aluminum alloy shells.

The required aluminum honeycomb material properties are:

nominal density = 4.5 pcf;
crush strength = 320 psi;
compressive strength = 700 psi (typical) and 500 psi (minimum).

The CY-MPC canister is longer than the Yankee-MPC canister and a single stainless steel spacer, installed below the canister, is used. The CY-MPC spacer is formed by a series of concentric rings welded to a stainless steel base plate and is nominally 12.7 inches high and 70.6 inches in diameter.

THIS PAGE INTENTIONALLY LEFT BLANK

load-bearing members of the canister maintain a factor of safety greater than five based on material ultimate strength. The hoist rings are designed with a 5 to 1 safety factor based on ultimate. Therefore, the lifting requirements are satisfied. Each lifting device in a three-point lift would experience the following load, F, when lifting the canister (the total load is based on the dead weight of the loaded canister with a dynamic load factor of 10%):

$$F = \frac{54{,}730 \times 1.1}{3} = 20{,}068 \text{ lb}$$

The hoist rings used to lift the canister have a rated load capacity of 24,000 pounds with a 5 to 1 safety factor based on material ultimate strength (American Drill Bushing Co.). The length of the hoist ring bolt thread length is 2.23 inches. The following calculation (using formula from Machinery's Handbook) demonstrates that the bolt length is adequate to develop the full strength of the hoist ring.

Definition of Terms

- D = basic major diameter of bolt threads = 1.5 inches
- n = number of threads per inch = 6
- A_t = tensile area of the bolt thread (in^2)
- L_e = minimum thread engagement length for mating materials with equal tensile strengths (in.)
- $K_n max$ = maximum minor diameter of lid (internal) thread = 1.35 inches
- $E_s min$ = minimum pitch diameter of bolt (external) threads = 1.3812 inches
- A_s = shear area of bolt threads (in^2)
- A_n = shear area of lid threads (in^2)
- $D_s min$ = minimum major diameter of bolt (external) threads = 1.4794 inches
- $E_n max$ = maximum pitch diameter of lid (internal) threads = 1.4022 inches
- Q = length of thread engagement required to prevent shearing when the mating thread materials are different tensile strengths (in.)
- J = scale factor for calculation of Q
- H = height of sharp "V" thread = 0.1443 inches

Hoist ring material = 4140 High strength alloy steel
Tensile strength of 4140 = 180,000 psi
Hoist ring thread = 1-1/2 - 6 UNC
Structural lid material = Type 304 L stainless steel
Temperature of structural lid = 250°F (Maximum calculated temperature = 209°F, Table 3.4-1)
Tapped hole in structural lid = 1-1/2 - 6 UNC

For steels up to 100,000 psi tensile strength, the tensile area of the bolt thread is given by:

$$A_t = 0.7854\left(D - \frac{0.9743}{n}\right)^2$$

$$A_t = 0.7854\left(1.5 - \frac{0.9743}{6}\right)^2 = 1.4053\ in^2$$

For mating materials having equal tensile strengths, the minimum length of thread engagement is given by:

$$L_e = \frac{2A_t}{3.1416K_n max\left[\frac{1}{2} + 0.57735n\left(E_s min - K_n max\right)\right]}$$

L_e = 1.0898 inches

For mating materials of differing tensile strengths:

$$J = \frac{A_s \text{ x tensile strength of bolt thread material}}{A_n \text{ x tensile strength of lid thread material}}$$

The shear areas are calculated as follows:

$$A_s = 3.1416nL_eK_n max\left[\frac{1}{2n} + 0.57735\left(E_s min - K_n max\right)\right]$$

A_s = 2.8106 in^2

$$A_n = 3.1416nL_eD_s min\left[\frac{1}{2n} + 0.57735\left(D_s min - E_n max\right)\right]$$

A_n = 3.887 in^2

At a temperature of 250°F, the ultimate strength of Type 304L stainless steel is 63,550 psi.

$$J = \frac{A_s x (S_u)_{bolt}}{A_n x (S_u)_{lid}}$$

$$= 2.048$$

The length of thread engagement necessary to prevent shearing is:

$$Q = JL_e$$

$$Q = (2.048)(1.0898) = 2.23 \text{ in.}$$

The following calculation determines the minimum required thread engagement length to meet the minimum Factors of Safety based on the actual load that the threads must support.

Minimum thread engagement ($L_{th,min}$) based on yield shear strength of lid material (304 L):

$F = 20.08$ kips
$S_m = 16.7$ ksi
$\tau_{allow.\ yield} = 10$ ksi (0.6×16.7)
$F.S._{yield,\ min} = 3$

$\tau_{max} = \tau_{allow.\ yield} / F.S._{yield,\ min} = 10 / 3 = 3.33$ ksi
$A_{min} = F / \tau_{max} = 20.08 / 3.33 = 6.03$ in^2

$$L_{th,min} = \frac{A_n}{\pi n D_{s,min}\left[\frac{1}{2n} + 0.57735\left(D_{s,min} - E_{n,max}\right)\right]} = \frac{6.03}{3.57}$$

$L_{th,min} = 1.69$ inches based on Yield Factor of Safety requirement

Minimum thread engagement ($L_{th,min}$) based on ultimate shear strength of lid material (304 L):

$F = 20.08$ kip
$S_u = 63.55$ ksi
$\tau_{allow.\ ultimate} = 26.7$ ksi $(0.42S_u)$
$F.S._{ultimate,\ min} = 5$

$\tau_{max} = \tau_{allow.\ ultimate} / F.S._{ultimate,\ min} = 26.7 / 5 = 5.34$ ksi

$A_{min} = F / \tau_{max} = 20.08 / 5.34 = 3.76\ in^2$

$$L_{th,min} = \frac{A_n}{\pi n D_{s,min}\left[\frac{1}{2n} + 0.57735\left(D_{s.min} - E_{n,max}\right)\right]} = \frac{3.76}{3.57}$$

$L_{th,min}$ = 1.05 inches based on Ultimate Factor of Safety requirement

The yield strength factor of safety dictates that the minimum thread engagement length required to meet ANSI N14.6 requirements is 1.69 inches; therefore, the hoist ring bolt thread length of 2.23 inches is adequate.

The structural adequacy of the canister structural lid and weld was evaluated using a finite element representation of the upper portion of the canister using the ANSYS program. As shown in Figure 2.5.1-5, the model represents one-half (180° section) of the upper 50-inches of the canister (including the structural and shield lids). The lids and shell in the model are comprised of SOLID45 elements. CONTAC52 elements are used to model the interaction between the structural lid and the canister shell and between the shield lid and the canister shell, just below the respective lid weld joints. The size of the CONTAC52 gaps was determined from nominal dimensions of contacting components. COMBIN40 elements are used between the structural and shield lids in the axial direction and between the shield lid and the backing ring. These gaps are assigned small gap sizes of 1E-8 inches. All gap/spring elements are assigned a stiffness of 1E8 lb/inch.

To enforce symmetry at the boundary of the model (in the x-y plane), all nodes on the x-y symmetry plane were restrained perpendicular to the symmetry plane (UZ). In addition, the nodes in the x-z plane at the bottom of the model were restrained in the axial direction.

Load-bearing members of a lifting device must be capable of lifting three (3) times the combined weight of the shipping container with which it will be used, plus the weight of intervening components of the lifting device without exceeding the tensile yield strength of their materials of construction. In addition, the lifting components must be capable of lifting five (5) times that combined weight without exceeding the ultimate tensile strength of the materials. NUREG-0612 also requires that the lifting loads must be based on the combined maximum static and dynamic loads that could be imparted on the handling device based on characteristics of the crane that will be used. A dynamic load factor of 10% has been applied.

To simulate the lifting of the canister by a three-point lifting device (the lifting configuration is actually two independent 3-point lifting devices), point loads equal to one-third of the total canister and contents weight plus a dynamic loading factor of 10% were applied to the model.

Because the model represents a half section of the canister, only two point loads were applied 120° apart as shown in Figure 2.5.1-5. Because of the symmetry conditions of the model, the force applied to the node on the symmetry plane was one-half of the value applied at the other location.

The maximum stress intensity generated in the canister model from the applied lifting forces was 3,753 psi, which occurs in the structural lid where the lifting loads were applied (see Figure 2.5.1-6).

As stated previously, the maximum stress intensity in the canister lifting model occurs in the structural lid that is constructed of Type 304L stainless steel. The yield strength (S_y) of Type 304L stainless steel at 250°F is 20,300 psi. The ultimate strength (S_u) of Type 304L stainless steel at 250°F is 63,550 psi.

The factor of safety (FS) for the canister lift based on yield strength is:

$$FS = \frac{S_y}{S_{INT}} = \frac{20{,}300 \text{ psi}}{3{,}753 \text{ psi}} = 5.40 > 3$$

The factor of safety for the canister lift based on ultimate strength is:

$$FS = \frac{S_u}{S_{INT}} = \frac{63{,}550 \text{ psi}}{3{,}753 \text{ psi}} = 16.93 > 5$$

2.5.1.3.2 CY-MPC Canister Lifting

The adequacy of the CY-MPC canister lifting devices is demonstrated by considering each of the hoist rings, the canister structural lid and the weld that joins the structural lid to the canister shell. Lifting of the canister employs redundant three-legged lifting slings for single failure proof lifting in accordance with NUREG-0612.

When considering a three-point lifting configuration, the load-bearing members of the canister maintain a factor of safety greater than three based on material yield strength. Additionally, the load-bearing members of the canister maintain a factor of safety greater than five based on

material ultimate strength. The hoist rings are designed with a 5 to 1 safety factor based on material ultimate strength. Therefore, the lifting requirements are satisfied.

Each lifting device in a three-point lift would experience the following load, F, when lifting the canister (the total load is based on the dead weight of the loaded canister with a dynamic load factor of 10%):

$$F = \frac{66{,}000 \text{ lb} \times 1.1}{3} = 24{,}200 \text{ lb}$$

The hoist rings used to lift the canister have a rated load capacity of 30,000 pounds with a 5 to 1 safety factor based on material ultimate strength. The length of the hoist ring bolt is 2.0 inches. From Machinery's Handbook, 25th Edition, the shear area of the structural lid bolt hole threads (A_n) is calculated as:

$$A_n = 3.1416 n L_e D_s \min\left[\frac{1}{2n} + 0.57735(D_s \min - E_n \max)\right]$$

$$= 3.1416(4.5)(2.0)(1.9751)\left[\frac{1}{2(4.5)} + 0.57735(1.9751 - 1.8681)\right] = 9.654 \text{ in}^2$$

where:

n = 4.5, threads per inch
L_e = 2.0 in., bolt thread engagement length
$D_s$min = 1.9751 in., minimum major diameter–external thread
$E_n$max = 1.8681 in., maximum pitch diameter–internal thread

The shear stress, τ, in the structural lid bolt hole threads is calculated as:

$$\tau = \frac{F_x}{A_n} = \frac{24{,}200 \text{ lb}}{9.654 \text{ in}^2} = 2{,}507 \text{ psi}$$

The canister structural lid is constructed of SA240, Type 304L stainless steel. At a temperature of 300°F (conservative), the Type 304L stainless steel yield strength is 19,200 psi and the ultimate strength is 60,900 psi. Thus, when the thread shear stress of 2,507 psi is compared to the structural lid yield and ultimate strengths, the lifting load factors of safety are:

$$(F.S.)_{yield} = \frac{0.6S_y}{\text{shear stress}} = \frac{11{,}520\ \text{psi}}{2{,}507\ \text{psi}} = 4.6 \quad (>3)$$

$$(F.S.)_{ultimate} = \frac{0.5S_u}{\text{shear stress}} = \frac{30{,}450\ \text{psi}}{2{,}507\ \text{psi}} = 12.1 \quad (>5)$$

These factors of safety meet the NUREG-0612 criteria for a redundant lifting system.

The minimum thread engagement (L_{minth}), based on the yield shear strength of the Type 304L lid material is:

$F_x = 24.20$ kip
$0.6S_y = 11.52$ ksi
$F.S._{yield,\ min} = 3$

$(\tau_{max})_{allow} = 0.6S_y / F.S._{yield,\ min} = 11.52\ \text{ksi} / 3 = 3.84\ \text{ksi}$
$A_{min} = F / (\tau_{max})_{allow} = 24.20\ \text{kip} / 3.84\ \text{ksi} = 6.30\ \text{in}^2$

$$L_{minth} = \frac{A_{min}}{\pi n D_{s\,min}\left[\frac{1}{2n} + 0.57735\left(D_{s\,min} - E_{n\,max}\right)\right]} = \frac{6.30}{4.83}$$

$L_{minth} = 1.30$ inches, based on the material yield Factor of Safety (F.S.) requirement of 3.

The minimum thread engagement (L_{minth}), based on the ultimate shear strength of the Type 304L lid material is:

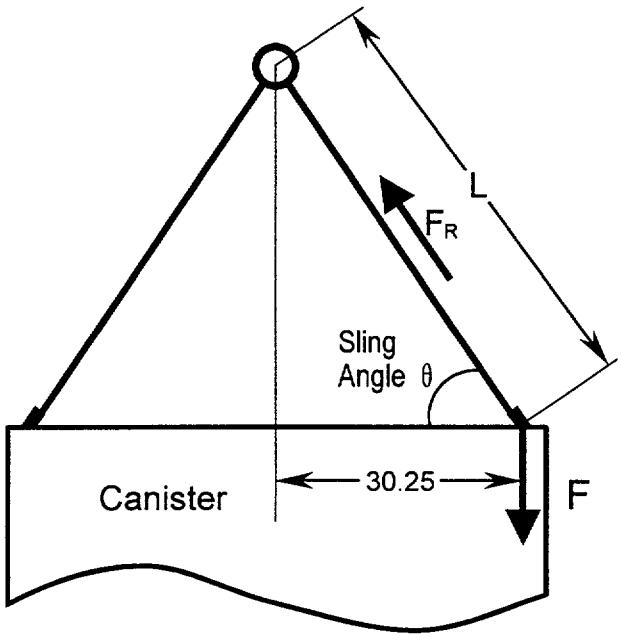
$F_x = 4.20$ kip
$0.5S_u = 30.45$ ksi
$F.S._{ultimate,\ min} = 5$
$(\tau_{max})_{allow} = 0.5S_u / F.S._{ultimate,\ min} = 30.45\ \text{ksi} / 5 = 6.09\ \text{ksi}$
$A_{min} = F / (\tau_{max})_{allow} = 24.20\ \text{kip} / 6.09\ \text{ksi} = 3.97\ \text{in}^2$

$$L_{minth} = \frac{A_{min}}{\pi n D_{s\,min}\left[\frac{1}{2n} + 0.57735\left(D_{s\,min} - E_{n\,max}\right)\right]} = \frac{3.97}{4.83}$$

L_{minth} = 0.82 inch, based on the ultimate Factor of Safety requirement of 5.

Based on the calculated thread engagement lengths, the minimum required engagement length is 1.3 inches based on the yield strength Factor of Safety. This minimum required thread engagement length is bounded by the actual total length of the hoist ring bolt thread engagement, 2.0 inches.

The hoist rings are rated at 30,000 lbs with a safety factor of 5.



The relation between the tension in the sling and thus the load on the swivel hoist ring (F_R) is:

$$F_R = \frac{F}{\sin\theta}$$

where:

F_R = the load on the swivel hoist ring

F = the handling load on the hoist ring (66,000 lb × 1.1/3)

F_R is limited to 30,000 lb, the load rating (with a 5:1 safety factor) of the swivel hoist ring. The minimum sling angle (θ_{min}) is then determined as:

$$\theta_{min} = \sin^{-1}\frac{F}{F_R} = \sin^{-1}\frac{24{,}200}{30{,}000} = 53.8°$$

For a slight additional margin, the minimum sling angle is set at 60°, requiring a minimum sling length (L) of:

$$L = \frac{30.25}{\cos\theta} = 60.5 \text{ in}$$

Therefore, the minimum allowable distance from the master link of the sling to the top of the canister is $60.5 \sin 60^\circ = 52.4$ inches.

The structural adequacy of the canister structural lid and weld is evaluated using a finite element representation of the upper portion of the canister using the ANSYS program. As shown in Figure 2.5.1-5, the model represents one-half (180° section) of the upper 50-in. of the canister (including the structural and shield lids). The lids and shell are modeled using SOLID45 elements. CONTAC52 elements are used to model the interaction between the structural lid and the canister shell and between the shield lid and the canister shell, just below the respective lid weld joints. The size of the CONTAC52 gaps is determined from nominal dimensions of contacting components. COMBIN40 elements are used between the structural and shield lids in the axial direction and between the shield lid and the backing ring. These gaps are assigned small gap sizes of 1E-8 inches. All gap/spring elements are assigned a stiffness of 1E8 lbs/in.

To enforce symmetry at the boundary of the model (in the x-y plane), all nodes on the x-y symmetry plane are restrained perpendicular to the symmetry plane (UZ). In addition, the nodes in the x-z plane at the bottom of the model are restrained in the axial direction.

Load-bearing members of a lifting device must be capable of lifting three (3) times the combined weight of the shipping container with which it will be used, plus the weight of intervening components of the lifting device without exceeding the tensile yield strength of their materials of construction. In addition, the lifting components must be capable of lifting five (5) times that combined weight without exceeding the ultimate tensile strength of the materials. NUREG-0612 also requires that the lifting loads must be based on the combined maximum static and dynamic loads that could be imparted on the handling device based on characteristics of the crane that will be used. A dynamic load factor of 10% has been applied.

To simulate the lifting of the canister by a three-point lifting device (the lifting configuration is actually two independent three-point lifting devices), point loads equal to one-third of the total canister and contents weight plus a dynamic loading factor of 10% are applied to the model. The

load is applied in the axial direction of the canister since the horizontal load component due to the angled hoist rings has an insignificant effect on the stresses in the structural lid weld and canister shell. Because the model represents a half section of the canister, only two point loads are applied 120° apart as shown in Figure 2.5.1-5. Because of the symmetry conditions of the model, the force applied to the node on the symmetry plane is one-half of the value applied at the other location. A temperature of 250°F is conservatively used to determine allowable stresses.

The maximum stress intensity generated in the canister model from the applied lifting forces is 4,482 psi, which occurs in the structural lid where the lifting loads are applied (Figure 2.5.1-7).

The maximum stress intensity in the canister lifting model occurs in the structural lid that is constructed of Type 304L stainless steel. The yield strength (S_y) of Type 304L stainless steel at 250°F is 20,300 psi. The ultimate strength (S_u) of Type 304L stainless steel at 250°F is 63,550 psi.

The factor of safety (FS) for the canister lift based on yield strength is:

$$FS = \frac{S_y}{S_{INT}} = \frac{20{,}300 \text{ psi}}{4{,}482 \text{ psi}} = 4.53 > 3$$

The factor of safety for the canister lift based on ultimate strength is:

$$FS = \frac{S_u}{S_{INT}} = \frac{63{,}550}{4{,}482} = 14.18 > 5$$

2.5.1.3.3 Shield Lid

The shield lid lifting system uses three 1 1/4 -7 UNC-2B threaded holes located on a 60.5 inch bolt circle. The three holes are equally spaced. The shield lid material is Type 304 stainless steel. The weight of the shield lid is 5,390 pounds.

The shield lid is lifted using a wire-rope sling that is load-rated for not less than the weight of the shield lid. The sling is attached to the lid using hoist-eyes that are threaded into the shield lid.

2.5.1.3.4 Structural Lid

The structural lid lifting system uses six 1 1/4 -7 UNC-2B threaded holes located on a 60.5 inch bolt circle. The six holes are equally spaced. The structural lid material is Type 304L stainless steel. The weight of the structural lid is 3,230 pounds.

The structural lid is lifted using a wire-rope sling that is load-rated for not less than the weight of the structural lid. The sling is attached to the lid using three equally spaced hoist-eyes that are threaded into the structural lid.

2.5.1.3.5 Empty Canister and Basket

The empty canister and basket lifting system uses eight hoist eyes threaded into holes located in the top nuts as part of the basket assembly. The holes are on a 62.5-inch bolt circle. The top nut material is Type 304 stainless steel. The weight of the empty canister and basket is 15,510 pounds.

The empty canister and basket are lifted using two wire-rope slings that are each load-rated for not less than the weight of the empty canister and basket assembly. The primary sling is attached to the basket using four equally spaced hoist-eyes that are threaded into the top nuts. The secondary (redundant) sling uses four equally spaced hoist eyes that are threaded into the remaining four top nuts.

Figure 2.5.1-1 Lifting Trunnion Geometry

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 2.5.1-2 Trunnion Weld Geometry

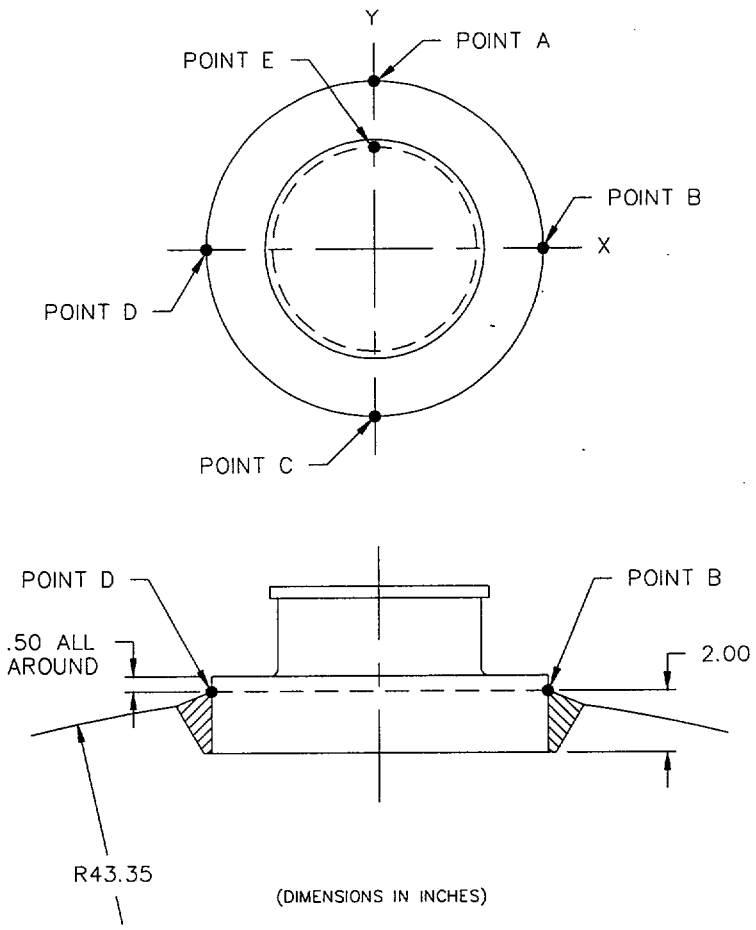


Figure 2.5.1-3 Sling Inclination Angle for Outer Lid Lifting

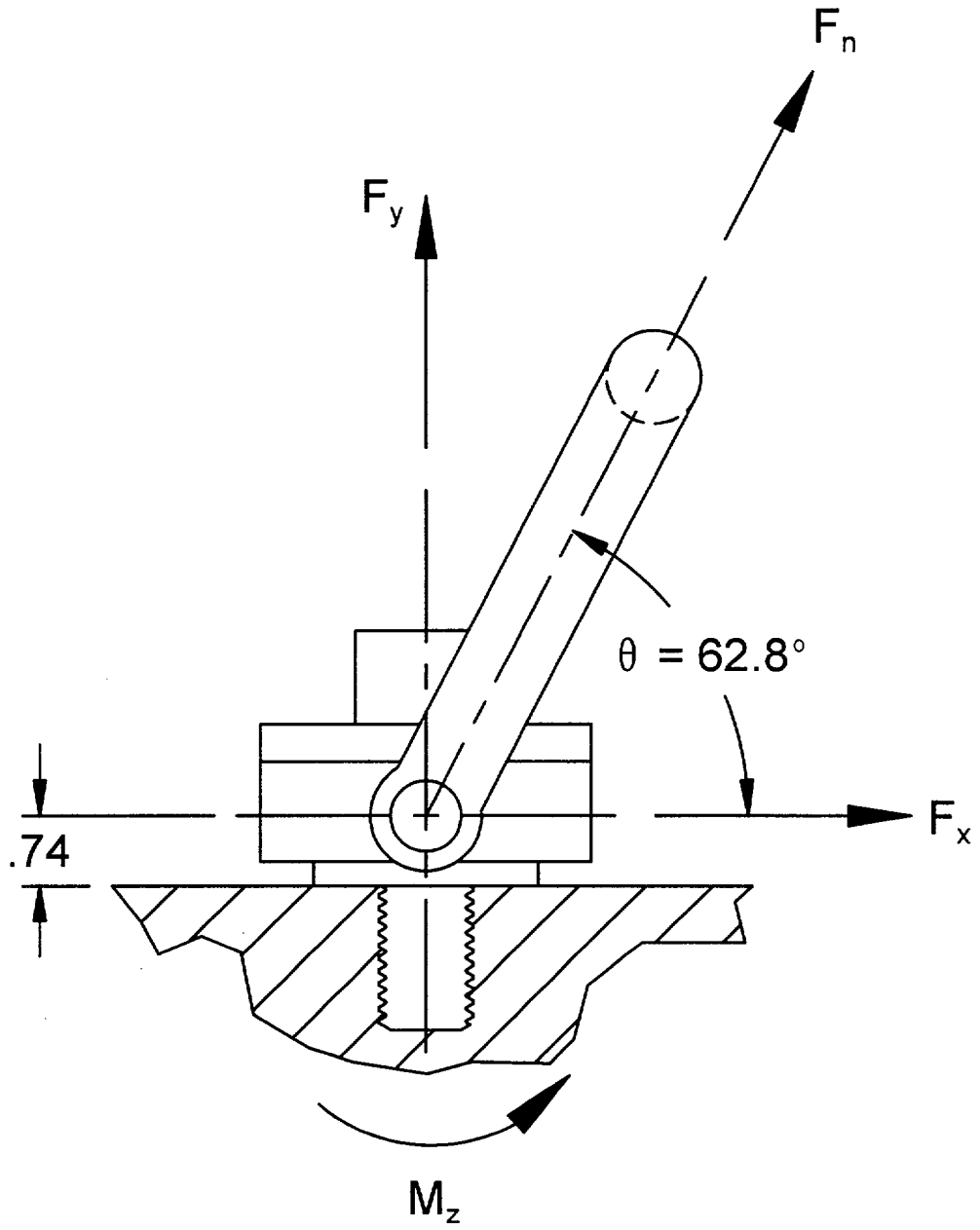


Figure 2.5.1-4 Sling Inclination Angle for Inner Lid Lifting

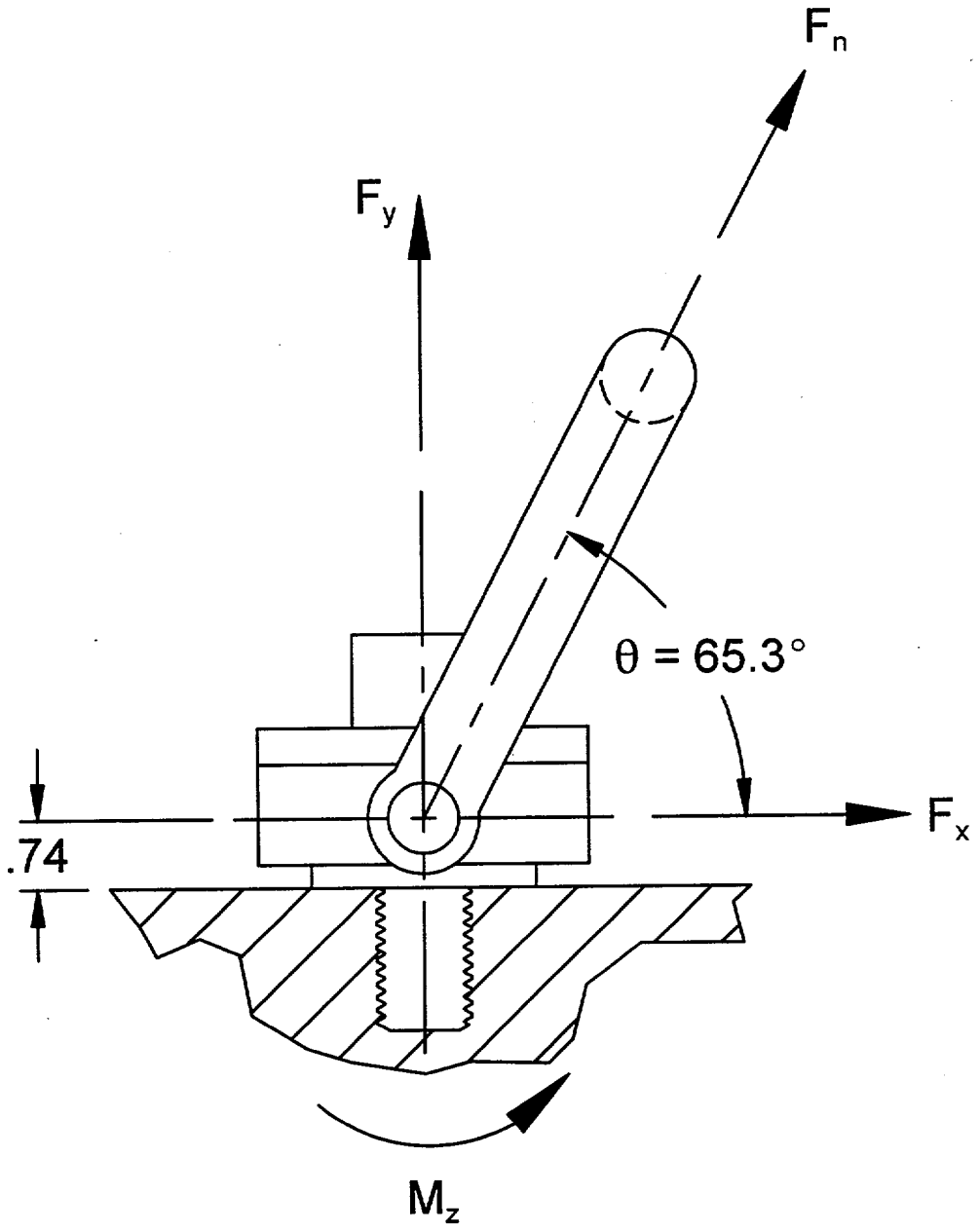


Figure 2.5.1-5 Canister Lift Finite Element Model

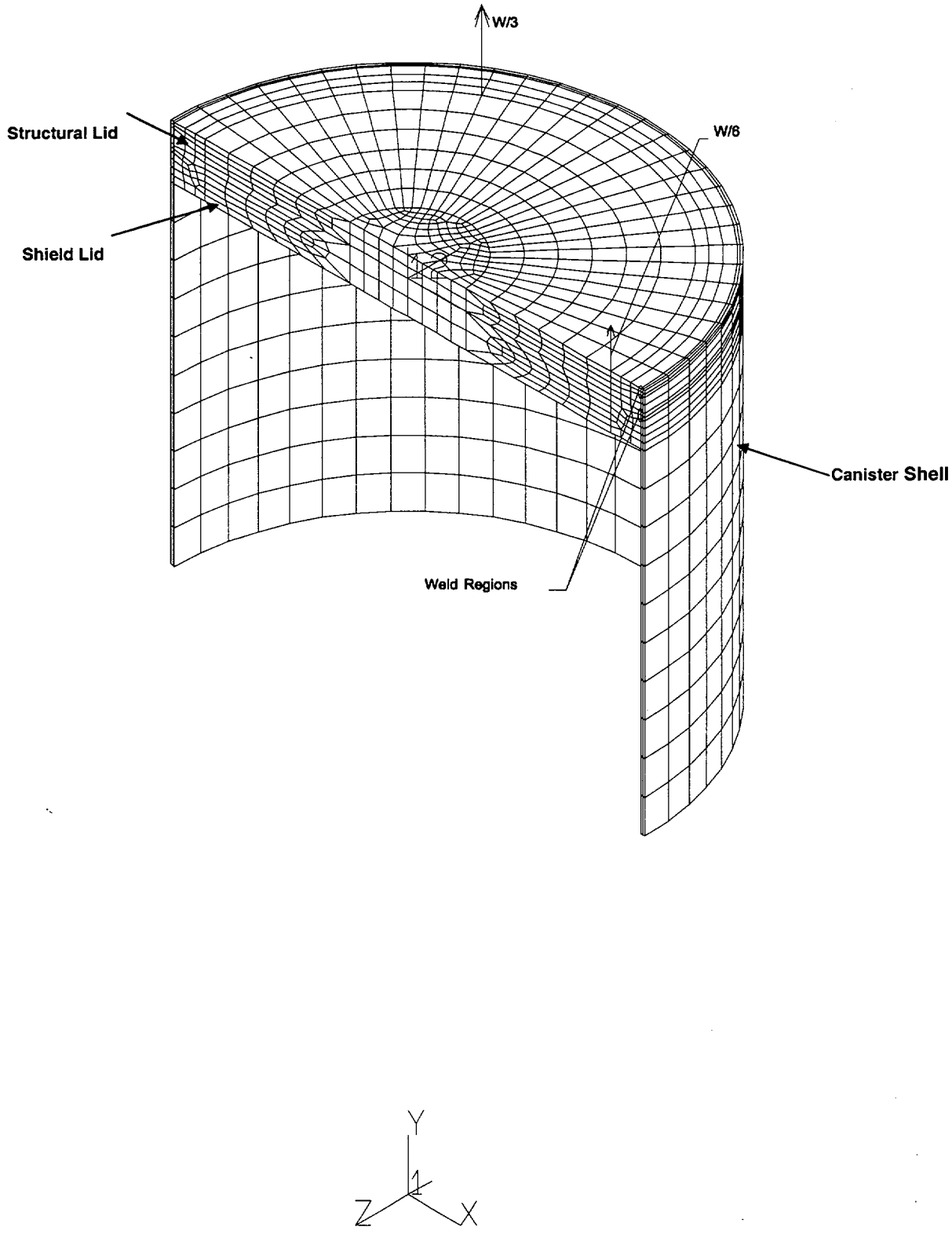


Figure 2.5.1-6 Yankee-MPC Canister Lift Model Stress Intensity Contours (psi)

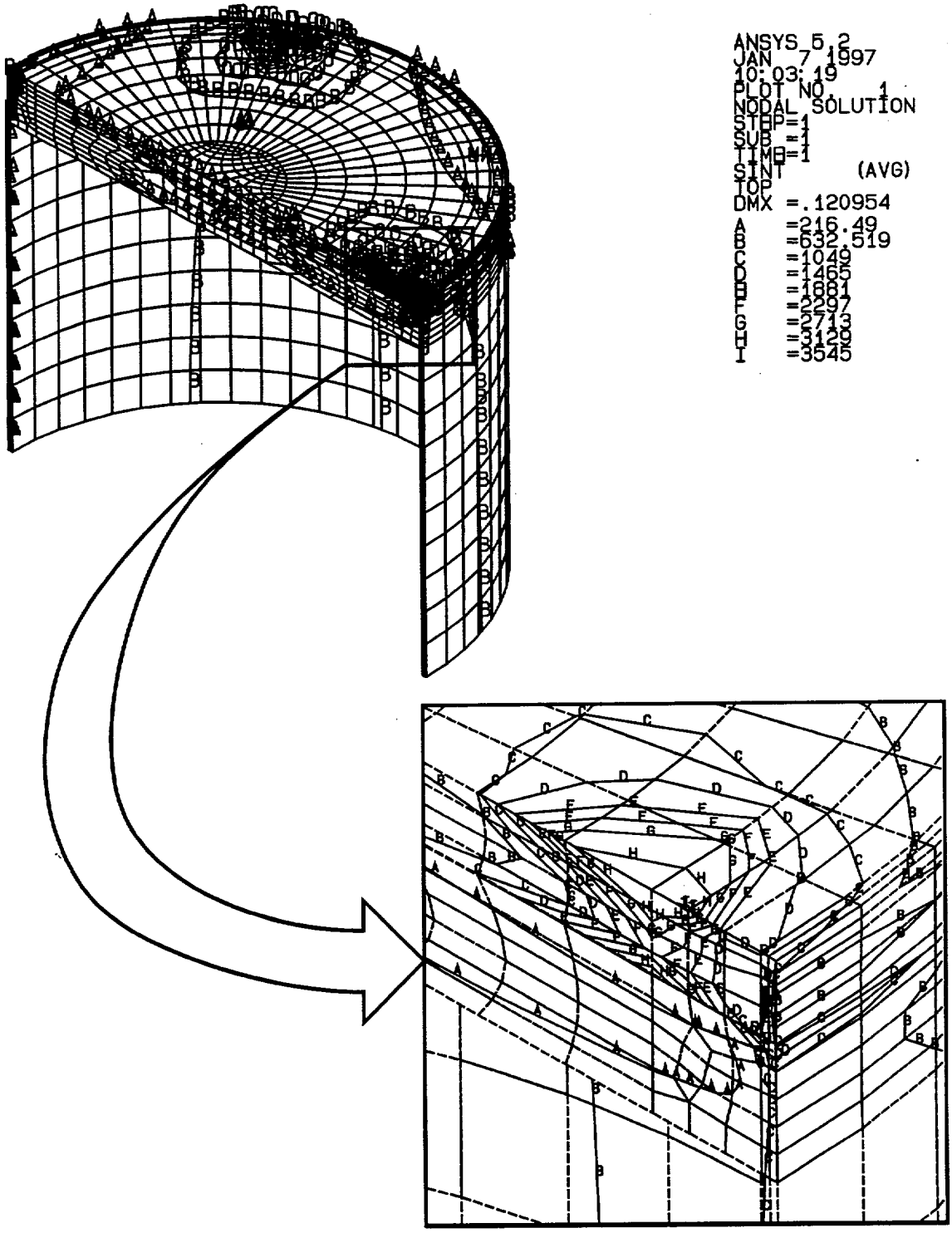
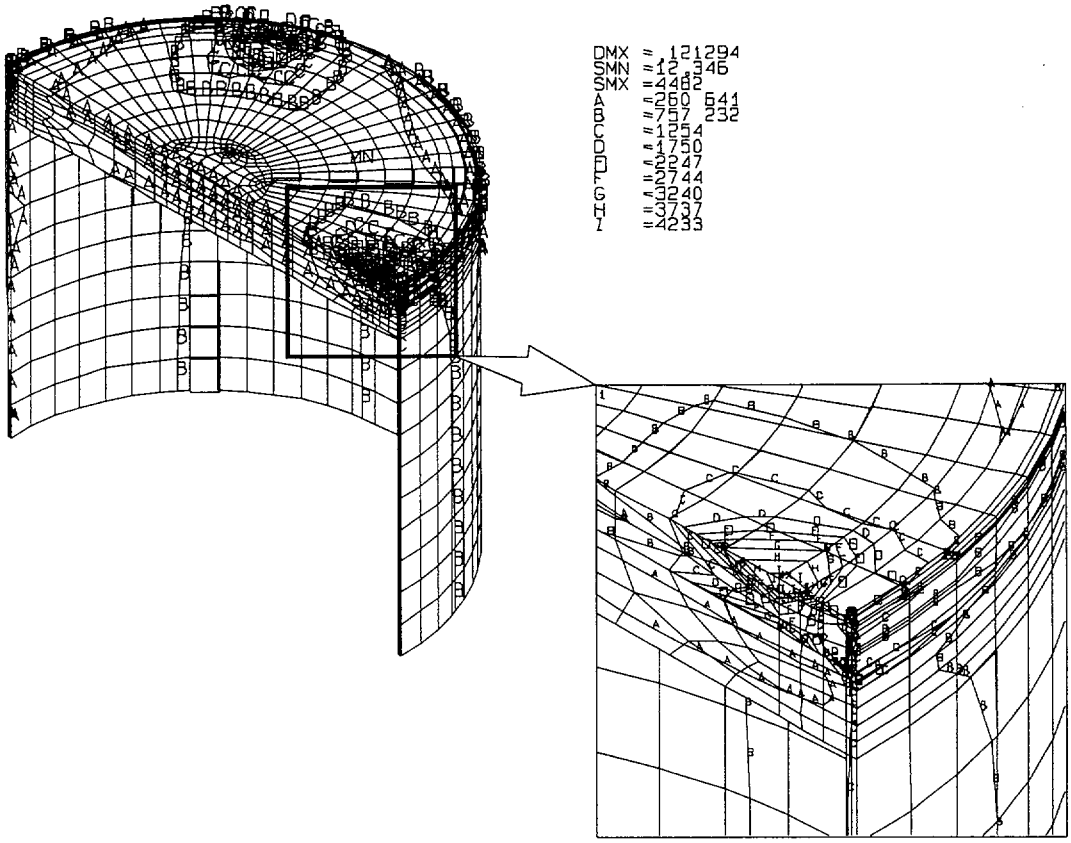


Figure 2.5.1-7 CY-MPC Canister Lift Model Stress Intensity Contours (psi)



2.6.1 Heat

The NAC-STC body and closure lids are analyzed for structural adequacy in accordance with the requirements of 10 CFR 71.71(c)(1) Heat (normal condition of transport). The cask is loaded, ready for shipment and supported in the horizontal position with an ambient temperature environment of 100°F, an assumed internal pressure of 50 psig, maximum decay heat load, maximum solar insolation, and still air.

2.6.1.1 Heat Condition for the NAC-STC Cask in the Directly Loaded Fuel and Yankee-MPC Configurations

The stress analysis of the cask is performed using both the two-dimensional and the three-dimensional finite element models and the ANSYS computer program. For the two-dimensional analysis, the cask is modeled as an axisymmetric structure using ANSYS STIF42 isoparametric elements. The individual loading conditions of thermal heat, internal pressure, and bolt preload are analyzed using a two-dimensional axisymmetric model, because both the cask structure and the loads are axisymmetric. By contrast, the individual gravity loading condition, and the combined loading conditions must be analyzed using the three-dimensional finite element model, since the gravity loading condition is not axisymmetric. The ANSYS computer program is described in Section 2.10.1.1. The finite element model descriptions are provided in Section 2.10.2.1. The temperature-dependent material properties considered in the analysis are documented in Section 2.3.

For the heat condition, the cask is structurally loaded due to closure lid bolt preload, internal pressure, thermal heat, and gravity. The following four categories of load are considered on the cask:

1. Closure lid bolt preload – For the NAC-STC directly loaded and the Yankee-MPC configurations, the required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3. The bolts are modeled as beam (ANSYS STIF3) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. For analysis purposes, a conservatively assumed internal pressure of 50 psig is applied on the interior surfaces of the cask cavity in the outward normal direction. The 50 psig is conservative, based on the calculated maximum normal operating cavity pressure (MNOP) of 1.8 atmospheres absolute (12 psig) for fuel loaded directly into the cask cavity. The calculated MNOP in the cask cavity for canistered fuel is 1.77 atmospheres absolute (11.31 psig). The cavity pressure is even less for the canistered GTCC waste because no fuel rod fill-gas is present. The pressure loading region includes the lid and upper body forging mating surfaces outward to the inner lid seal centerline.

3. Thermal - The heat transfer analyses performed for maximum normal operating conditions determine the cask temperature distribution for the heat condition. The heat condition considers the cask to be subjected to an ambient temperature of 100°F, with maximum decay heat load (for directly loaded fuel) and maximum solar insolation, in still air. The maximum decay heat load for Yankee Class canistered fuel is 12.5 kW and is 2.9 kW for Yankee GTCC waste. The directly loaded fuel configuration is considered to bound the temperatures associated with the Yankee-MPC configurations. For The cask temperature distribution, obtained for this heat condition, is used as an input to the ANSYS analysis to determine the stresses in the cask. The ANSYS analysis determines the stresses resulting from the thermal expansion of the cask from its initial, 70°F, condition to its normal transport temperature condition. These stresses include the effects of the differential thermal growth within the components, which result from the temperature difference across the walls of the cask. The cask temperature distribution is also used in the ANSYS structural analysis to determine the values of the temperature-dependent material properties.

4. Gravity - The mechanical loads consist of gravity acting on the cask structure and its contents. The cask is assumed to be loaded and resting in the horizontal position on the front and rear cask supports. Mechanical loads resulting from a 1 g application of the total weight (250,000 lbs for the NAC-STC directly loaded and Yankee-MPC configurations) of the cask structure and contents are imposed on the model. The design weight of the empty cask (194,000 lbs) is imposed on the mass of the cask model.

   The weight of the cavity contents (56,000 lbs) for directly loaded fuel is imposed on the model as a contents pressure on the contact surface of the cask cavity (Section 2.10.2.2.1

Regulatory Guide 7.6 requires that the range of primary plus secondary stress intensities between any two normal conditions of transport be less than 3.0 S_m. Therefore, it is necessary to evaluate the range of primary plus secondary stresses between all of the recognized normal conditions of transport: including the heat, cold, 1-foot end drop, 1-foot side drop, and 1-foot corner drop conditions. A simple, straightforward, and very conservative method of showing compliance with the 3.0 S_m criteria is to establish an allowable stress limit criteria of 1.5 S_m for the range of primary plus secondary stress intensities between each normal condition and the ambient condition. If each normal condition meets the 1.5 S_m allowable stress intensity range criteria at all locations within the cask when paired with the ambient condition, then all pairs of normal conditions will meet the 3.0 S_m stress intensity range criteria.

Table 2.10.4-28 documents the range of primary plus secondary stress intensity between the heat condition and the unloaded, ambient condition. The maximum calculated primary plus secondary stress intensity is shown to be 24.3 ksi, which is less than 1.5 S_m. In conjunction with the 1.5 S_m criteria for the stress intensity range between the ambient condition and each of the other normal conditions, it is therefore concluded that the NAC-STC meets the 3.0 S_m criteria for the primary plus secondary stress intensity range for the heat condition. For the fatigue evaluation of the NAC-STC, Section 2.1.3.2 documents that the requirements of Regulatory Guide 7.6 are satisfied by the 3.0 S_m criteria for the extreme total stress intensity range limit.

The documentation of the adequacy of the NAC-STC in satisfying the buckling criteria for the stresses of the heat condition is presented in Section 2.10.5.

Since the margins of safety are all positive, the NAC-STC, therefore, satisfies the requirements of 10 CFR 71.71(c)(1) for the heat (normal transport) condition for the directly loaded fuel, the canistered fuel configuration and the canistered GTCC waste configuration.

2.6.1.2 Heat Condition for the NAC-STC Cask in the CY-MPC Configuration

The three-dimensional model and analyses used in the 1-foot side drop evaluation for the CY-MPC configuration are also used for the evaluation of the heat condition. The NAC-STC cask with the CY-MPC canistered configuration is modeled as a three-dimensional structure using ANSYS STIF45 isoparametric elements. A detailed description of the three-dimensional finite element model of the NAC-STC cask body for the canistered configurations is provided in Section 2.10.2.1.3. Since some of the loading contributions for the heat condition are

axisymmetric, and the NAC-STC cask body is the same geometry for all fuel configurations, results of the two-dimensional model and analyses are combined with the results of the three-dimensional model of the CY-MPC fuel configuration.

Four categories of loads are considered in this evaluation: closure lid bolt preload, internal pressure, thermal expansion, and gravity loading:

1. Closure lid bolt preload – The required bolt preloads on the inner and outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as described in Section 2.10.2.2.3. The stresses corresponding to the bolt preload with a 50 psig internal pressure for the directly load configuration are reported in Table 2.10.4-1 (for the two dimensional axisymmetric model), and the maximum stress intensity is 1.9 ksi (Location U). To account for the preload and internal pressure for the CY-MPC configuration, the 1.9 ksi is added to the stress intensity due to the 1g lateral load.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. A pressure of 50 psig, which envelops the calculated pressure of 38.1 psig for this configuration, is effectively used by adding the 1.9 ksi (reported above for the bolt preload) to the stress intensity due to the 1 g lateral load.

3. Thermal - The ANSYS analysis determines the stresses arising from the thermal expansion of the cask from its initial 70°F condition, including the effects of the differential thermal growth within the components, which is a result of the temperature difference across the walls of the cask. The cask temperature distributions are also used in the ANSYS structural analyses to determine the values of the temperature-dependent material properties. The heat transfer analysis performed for maximum normal operating conditions determine the cask temperature distribution for the heat condition. The heat condition corresponds to a 100°F ambient temperature, a maximum decay heat load (17 kW), and full solar insolation.

   To bound the stresses arising from thermal expansion, the maximum gradient is used in the heat condition evaluation. The maximum temperature gradient is actually associated with the cold condition of –40°F with maximum decay heat and no solar insolation. To ensure that the minimum stress allowable is used, the allowables are taken at the

2.6.2 Cold

The NAC-STC body and closure lids are analyzed for structural adequacy in accordance with the requirements of 10 CFR 71.71(c)(2) Cold (normal condition of transport). The cask is loaded and ready for shipment in the horizontal position, with an ambient temperature environment of -40°F, an assumed internal pressure of 12 psig, no decay heat load, no solar insolation, and in still air and shade.

2.6.2.1 Cold Condition for the NAC-STC Cask in the Directly Loaded Fuel and Yankee-MPC Configurations

The stress analysis of the cask is performed using both the two-dimensional and the three-dimensional finite element models and the ANSYS computer program. For the NAC-STC directly loaded configuration two-dimensional analysis, the cask is modeled as an axisymmetric structure using ANSYS STIF42 isoparametric elements. The individual loading conditions of thermal cold, internal pressure, and bolt preload are analyzed using a two-dimensional axisymmetric model because both the cask structure and the load are axisymmetric. By contrast, the individual gravity loading condition and the combined loading conditions must be analyzed using three-dimensional finite element models, since the gravity loading condition is not axisymmetric. The ANSYS computer program is described in Section 2.10.1.1. The finite element model descriptions are provided in Section 2.10.2.1. The temperature-dependent material properties considered in the analysis are documented in Section 2.3.

For the cold condition, the cask is structurally loaded due to closure lid bolt preload, internal pressure, thermal cold, and gravity. The following four categories of load are considered on the cask:

1. Closure lid bolt preload – For the NAC-STC directly loaded and the Yankee-MPC configurations, the required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3. The bolts are modeled as beam (ANSYS STIF3) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and its maximum value is evaluated in Section 3.4.4. For analysis purposes for the cold condition, an internal pressure of 12 psig is applied on the interior surfaces of the cask cavity in the

outward normal direction. The calculated cavity pressure is -0.8 psia at -40°F for directly loaded fuel. Since the cask cavity is backfilled with helium to 1 atmosphere absolute (0 psig) at an ambient temperature, the cavity pressure at -40°F will be less than 12 psig for both the canistered fuel and the canistered GTCC waste configurations. The pressure loading region includes the lid and upper body forging mating surfaces outward to the inner lid seal centerline.

3. Thermal - The cold condition considers the cask to be subjected to an ambient temperature of -40°F, with no decay heat load and no solar insolation, in still air and shade. This cask temperature distribution calculated for the cold condition is used as an input to the ANSYS analysis to determine the stresses. The ANSYS analysis determines the stresses resulting from the thermal expansion or contraction of the cask from its initial 70°F condition to its normal transport temperature condition. These stresses include the effects of the differential thermal growth within the components, which result from the temperature difference across the walls of the cask. The cask temperature distribution is also used in the ANSYS structural analysis to determine the values of the temperature dependent material properties such as modulus of elasticity, density, and Poisson's ratio.

4. Gravity - The mechanical loads consist of gravity acting on the cask structure and its contents. The cask is assumed to be loaded and resting in the horizontal position on the front and rear cask supports. Mechanical loads resulting from a 1g application of the total weight (250,000 lbs for the directly loaded and Yankee-MPC configurations) of the cask structure and contents are imposed on the model. The weight of the empty cask (194,000 lbs) is imposed on the model as a deceleration on the mass of the cask model. The weight of the cavity contents (56,000 lbs) for directly loaded fuel is imposed on the model as a contents pressure on the contact surface of the cask cavity (see Section 2.10.2.2.1 for the contents pressure calculation). The weight of the cavity contents for the Yankee-MPC canistered fuel configuration is 55,590 pounds, including the top and bottom cask cavity spacers. For the canistered GTCC waste configuration, the weight of the cavity contents is 54,271 pounds. These weights include the cask cavity spacers.

Fabrication stresses are considered to be negligible as demonstrated in Section 2.6.11.

For the two-dimensional analyses, axisymmetric boundary conditions are applied to the two-dimensional finite element model because axisymmetry exists in the cask geometry and in the

loading contributions for the cold condition are axisymmetric, and the NAC-STC cask body is the same geometry for all fuel configurations, results of the two-dimensional model and analyses are combined with the results of the three-dimensional model of the CY-MPC fuel configuration.

Four categories of loads are considered in this evaluation: closure lid bolt preload, internal pressure, thermal expansion, gravity loading:

1. Closure lid bolt preload – The required bolt preloads on the inner lid and outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. Bolt preload is applied to the model by imposing initial strains to the blot shafts, as described in Section 2.10.2.2.3. The stresses corresponding to the bolt preload with a 12 psig internal pressure for the directly load configuration are reported in Table 2.10.4-2 (for the two-dimensional axisymmetric model), and the maximum stress intensity is 2.2 ksi (Location U). To account for the preload and internal pressure for the CY-MPC configuration, the 2.2 ksi is added to the stress intensity due to the 1g lateral load.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. For analysis purpose for the cold condition, an internal pressure of 12 psig is used, which envelop a backfill pressure of 0 psig. The 12 psig is effectively used by adding the 2.2 ksi (reported above for the bolt preload) to the stress intensity due to the 1g lateral load.

3. Thermal - The cold transfer analysis performed for maximum normal operating conditions determines the cask temperature distribution for the cold condition. The bounding cold load for the NAC-STC is for the directly loaded fuel of 22.1 kW, which is larger than the CY-MPC configuration 17 kW design cold load. The cold condition corresponds to a - 40°F ambient temperature, no decay heat and no solar insolation.

   To bound the stresses arising from thermal expansion, the maximum stress intensity of 7 ksi for the directly loaded fuel (Table 2.10.4-6, location R1) is added to maximum stress intensity of the other loading conditions for the cold condition of the CY-MPC configuration. This stress intensity bounds the actual cold condition described above. To ensure that the minimum stress allowable is used, the allowables are taken at the maximum temperature of the inner shell (331°F) for the cold condition described above. The temperature distribution for the canistered GTCC waste is considered to be enveloped by the 17 kW design basis cold load.

4. Gravity loads - The mechanical loads consist of gravity acting on the cask structure and it contents. The cask is assumed to be loaded and resting in the horizontal position on the front and rear cask supports. Mechanical loads resulting from a 1g application of the total weight (260,000 lbs) of the cask structure and contents are imposed on the model.

These loading conditions are identical to the 1 foot side drop evaluated in 2.6.7.2.2 for the CY-MPC configuration except the 1 foot drop condition employed 20g instead of 1g for the gravity load. Descriptions of the three-dimensional finite element model are contained in 2.6.7.2.2 and 2.10.2.1.3. To determine the maximum primary stress intensity for the cold condition, the stress intensity due to the 20g loading (in Tables 2.6.7.1-2 and 2.6.7.1-3) can be factored by 1/20 and then added to the stress intensity associated with the 50 psig pressure + bolt preload (2.2 ksi). The maximum primary stress intensity reported for P_m and $P_m + P_b$ for the 1-foot side drop are 11.5 ksi and 20.9 ksi, respectively. Factoring these by 1/20 and adding the result to 2.2 ksi for the pressure + bolt preload, results in 2.8 ksi and 3.2 ksi, respectively, for P_m and $P_m + P_b$. Using the minimum allowables of 19.6 ksi for P_m and 29.4 ksi for $P_m + P_b$, reported in Tables 2.6.7.1-4 and 2.6.7.1-5, the minimum margins of safeties for the cask body for the primary stress intensity P_m and $P_m + P_b$ are +6.0 and +8.2, respectively. It is concluded that the CY-MPC configuration satisfies the primary stress limits for the cold condition.

Using the methodology to evaluate the range of $P_m + P_b$ stress intensities described in 2.6.1.1, the allowable stress intensity of 1.5 S_m of 29.4 ksi should be compared to the bounding $P_m + P_b$ stress intensity. This value is obtained by adding the maximum thermal stress intensity of 7 ksi to 3.2 ksi to obtain 10.2 ksi. Since $10.2 < 29.4$ ksi, it is concluded that the CY-MPC configuration meets the 3.0 S_m criteria for the $P_m + P_b$ stress intensity range for the cold condition.

2.6.7.1 One-Foot End Drop

The NAC-STC is structurally evaluated for the normal condition of transport 1-foot end drop in accordance with the requirements of 10 CFR 71.71. In this event, the NAC-STC (equipped with an impact limiter over each end) falls through a distance of one foot onto a flat, unyielding, horizontal surface. The cask strikes the surface in a vertical position; consequently, an end impact on the bottom end or top end of the cask occurs. The types of loading involved in an end drop event are closure lid bolt preload, internal pressure, thermal, impact load, and inertial body load. There are six credible end impact conditions to be considered, according to Regulatory Guide 7.8:

1. Top end drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.
2. Top end drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.
3. Top end drop with -20°F ambient temperature, no decay heat load, and no solar insolation.
4. Bottom end drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.
5. Bottom end drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.
6. Bottom end drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

During an impact event, the cask body will experience a vertical deceleration. Considering the cask as a free body, the impact limiter will apply the load to the cask end to produce the deceleration. Since the deceleration represents an amplification factor for the inertial loading of the cask, the equivalent static method is adopted to perform the impact evaluations. The analyses consider the behavior of the cask to be linearly elastic. Additionally, the fabrication stresses are considered to be negligible (Section 2.6.11).

2.6.7.1.1 One-Foot End Drop Evaluation of the NAC-STC Cask in the Directly Loaded and Yankee-MPC Canistered Fuel Configurations

The NAC-STC cask is modeled as an axisymmetric structure using ANSYS STIF42 isoparametric elements. A detailed description of the two-dimensional finite element model of the NAC-STC is provided in Section 2.10.2.1.1.

Five categories of load—closure lid bolt preload, internal pressure, thermal, impact, and inertial body loads—are considered on the cask:

1. Closure lid bolt preload - The required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively, as calculated in Section 2.6.7.5. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.6.7.5. The bolts are modeled as beam (ANSYS STIF3) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. Pressures of 50 psig and 12 psig are applied on the interior surfaces of the cask cavity for the hot ambient and cold ambient cases, respectively. These pressures envelope the calculated pressures for cask configurations—directly loaded fuel (12 psig), canistered fuel (11.3 psig), and canistered GTCC waste (< 11.3 psig).

3. Thermal - The thermal conditions described in Sections 3.4.2 and 3.4.3 determine the cask temperature distributions for the following three combinations of ambient temperature, heat load, and solar insolation for directly loaded fuel:

   Condition 1. 100°F ambient temperature, with maximum decay heat load, and maximum solar insolation.

   Condition 2. -20°F ambient temperature, with maximum decay heat load, and no insolation.

   Condition 3. -40°F ambient temperature, with no decay heat load, and no insolation.

   The cask temperature distributions calculated for each of the three temperature conditions discussed above are used as inputs to the ANSYS analyses for the directly loaded fuel

Since all of the margins of safety for the 1-foot end drop condition are positive, the NAC-STC with the directly loaded fuel configuration satisfies the requirements of 10 CFR 71.71 for the normal condition of transport 1-foot end drop condition.

The weight of the directly loaded fuel configuration of the NAC-STC envelopes the weight of the Yankee-MPC canistered fuel and canistered GTCC waste configurations for the 1-foot end drop condition. Consequently, the requirements of 10 CFR 71.71 are also met for the Yankee-MPC configuration.

2.6.7.1.2 One-Foot End Drop Evaluation of NAC-STC in the CY-MPC Configuration

The NAC-STC cask with the CY-MPC canistered configuration is modeled as a three dimensional structure using ANSYS STIF45 isoparametric elements. A detailed description of the three-dimensional finite element model of the NAC-STC cask body for the canistered configurations is provided in Section 2.10.2.1.3. While the loading is axisymmetric, the three-dimensional model employed in this evaluation is also used for the 1-foot side drop orientation.

Five categories of loads are considered in this evaluation: closure lid bolt preload, internal pressure, thermal expansion, impact and inertial loading:

1. Closure lid bolt preload - The required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. The stresses corresponding to the bolt preload with a 50 psig internal pressure for the directly loaded configuration are reported in Table 2.10.4-1, and the maximum stress intensity is 1.9 ksi (Location U). To account for the preload and internal pressure for the CY-MPC configuration, the 1.9 ksi is added to the stresses due to the 1-foot end drop.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. A pressure of 50 psig , which envelopes the calculated pressure of 38.1 psig for this configuration, is effectively used by adding the 1.9 ksi (reported above for the bolt preload) to the stresses due to the 1-foot end drop.

3. Thermal - The ANSYS analysis determines the stresses arising from the thermal expansion of the cask from its initial 70°F condition, including the effects of the differential thermal growth within the components, which is a result of the temperature difference across the walls of the cask. The cask temperature distributions are also used in the ANSYS structural analyses to determine the values of the temperature-dependent material properties. Heat transfer analyses performed in Sections 3.4.2 and 3.4.3 determine the cask temperature distributions for the following two conditions for the canistered fuel configuration (an analysis for the third condition is not required):

   1. 100°F ambient temperature, maximum decay heat load (17 kW).
   2. -40°F ambient temperature, maximum decay heat load (17 kW), and no solar insolation.
   3. -40°F ambient temperature, no decay heat load, and no solar insolation.

   To bound the stresses arising from thermal expansion, the maximum stress intensity (8.1 ksi, Location G5) from Table 2.10.4-5 is added to the maximum stress intensity in the end drop evaluation. The maximum thermal stress intensity is associated with Thermal Condition 1. To ensure that the minimum stress allowable is used, the allowables are taken at the maximum temperature of the inner shell (331°F) for Thermal Condition 1. The temperature distribution for the canistered GTCC waste is considered to be enveloped by the 17 kW design basis heat load. Individual thermal cases are not evaluated since the design basis heat load of 22.1 kW for the directly loaded fuel envelops the 17 kW basis heat load for the CY-MPC configuration.

4. Impact loads - The impact loads are induced by the impact limiter acting on the cask end during an end drop condition. The impact loads are determined from the energy absorbing characteristics of the impact limiters, and the impact load is expressed in terms of the design cask weight (loaded or empty), multiplied by appropriate deceleration factors (g).

   Instead of representing the impact load as a pressure applied to the ends of the cask body, the impact limiter load is actually represented by the contact force generated by the gap elements connected at the ends of the cask. (Figure 2.6.7.2-3). It should be noted that the design weight of the cask is 260,000 pounds, which bounds the weight of the empty cask (187,400 lbs), plus the weight of the cavity contents (67,196 lbs) for the CY-MPC fuel

configuration. The weight of the cavity contents for the canistered fuel configuration equals that of the canistered GTCC waste configuration.

5. Inertial body load - The inertial effects, which occur during the end impact, are represented by equivalent static forces, in accordance with D'Alembert's principle. Inertial body load includes the weight of the empty cask (194,000 lbs). Inertial loads resulting from the weight of the empty cask are imposed by applying a 20g deceleration factor to the cask mass. The applied decelerations are determined by considering the crush strength and the geometry of the impact limiter, as explained in Section 2.6.7.4.

   The inertial load resulting from the contents design weight is represented as an equivalent static pressure load uniformly applied on the interior surface of the impacting end of the cask. The pressure corresponds to 20 times the contents weight. For the bottom end drop, the pressures are applied to the bottom of the cask cavity, and for the top end drop, the pressures are applied to the inner surface of the inner lid.

Maximum stress values are obtained for the sections shown in Figure 2.6.7.2-1 by linearizing the stresses along the indicated sections. Components and nodes associated with these sections are shown in Table 2.6.7.1-1. A maximum stress intensity for the load case of "Bolt Preload + 50 psi Internal Pressure" obtained from Table 2.10.4-1 is added to the stress intensity for impact load to obtain a stress intensity associated with the combined loading of bolt preload, pressure, thermal expansion, impact and inertial loadings.

The summary of the maximum membrane stresses (P_m) and membrane plus bending ($P_m + P_b$) are presented in Tables 2.6.7.1-2 through 2.6.7.1-5 for the top end drop and the bottom end drop. All margins of safety for the 1-foot end drop condition are positive. Therefore, the NAC-STC cask with the CY-MPC fuel configuration satisfies the requirements of 10 CFR 71.71 for the normal condition of transport 1-foot end drop condition.

Using the methodology to evaluate the range of primary plus secondary stress intensities described in 2.6.1.1, the allowable stress intensity of 1.5 S_m of 29.4 ksi should be compared to the bounding primary plus secondary stress intensity. The maximum stress intensity in Table 2.6.7.1-5 (6.1 ksi) corresponds to Section 10, which includes the 1.9 ksi stress for pressure + bolt preload. The largest thermal stress intensity occurs at Section 9, for the corresponding location in Table 2.10.4-5 is 1.8 ksi (Section B5). This results in a primary plus secondary stress intensity

of (1.8 + 5.3) 7.1 ksi. At Section 10, adding 6.1 ksi to the maximum thermal stress intensity of 8.1 ksi results in a primary plus secondary stress intensity of 14.2 ksi. These two combinations of stresses bound all other possible primary plus secondary stresses for the end drop condition. Since 14.2 < 29.4 ksi, it is concluded that the CY-MPC configuration meets the 3.0 S_m criteria for the primary plus secondary stress intensity range for the heat condition.

Table 2.6.7.1-1 Section Locations for Stress Evaluation (Maximums)

Section No.[1]	Component Name and Material	Inside Node	Section Location (in.)						
			X	Y	Z	Outside Node	X	Y	Z
1	Transition Shell – XM-19	197	35.5	146.1	0.0	165	37	146.1	0.0
2[2]	Inner Shell – 304	196	35.5	142.0	0.0	164	37	142.0	0.0
3	Inner Shell – 304	189	35.5	94.2	0.0	157	37	94.2	0.0
4	Bottom Forging – 304	130	35.5	14.5	0.0	123	38	14.5	0.0
5	Outer Shell – 304	280	40.7	14.5	0.0	328	43	14.5	0.0
6	Outer Shell – 304	300	40.7	103.2	0.0	358	43	103.2	0.0
7	Top Forging – 304	271	35.5	173.2	0.0	265	37.5	173.2	0.0
8	Top Forging – 304	317	40.7	173.2	0.0	435	43.4	173.2	0.0
9	Bottom Plate – 304	23	3.16	0.0	0.0	34	3.16	5.45	0.0
10	Bottom Forging – 304	53	3.16	7.45	0.0	65	3.16	13.65	0.0
11	Bottom Plate – 304	22	35.5	0.0	0.0	32	35.5	5.45	0.0
12	Bottom Forging – 304	52	35.5	7.45	0.0	62	35.5	13.65	0.0
13	Inner Lid – 304	486	3.52	178.68	0.0	787	3.52	187.65	0.0
14	Outer Lid – 17-4	514	3.52	187.68	0.0	500	3.52	192.96	0.0
15	Inner Lid – 304	485	35.5	178.68	0.0	796	35.5	187.65	0.0
16	Outer Lid – 17-4	497	35.5	187.68	0.0	495	35.5	192.96	0.0

1. Sections are shown in Figure 2.6.7.2-1.
2. This section is at the boundary of transition shell and inner shell. Allowables for 304 Stainless Steel are used for evaluation.

Table 2.6.7.1-2 CY-MPC Critical P_m Stress Summary; 1-ft Top End Drop

Section No.	P_m Stresses (ksi)						Principal Stresses (ksi)			S.I. Impact (ksi)	S.I. Bolt Preload + Pressure** (ksi)	S.I. Total (ksi)	Allowable Stress* (ksi) S_m	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}	S1	S2	S3					
1	0.0	-1.6	0.0	0.0	0.0	0.0	0.0	0.0	-1.6	1.6	1.9	3.5	31.0	7.9
2	0.0	-1.5	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	1.6	1.9	3.5	19.6	4.6
3	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	1.2	1.9	3.1	19.6	5.3
4	0.0	-0.5	0.2	-0.1	0.0	0.0	0.2	0.0	-0.5	0.7	1.9	2.6	19.6	6.5
5	0.0	-0.2	0.2	0.0	0.0	0.0	0.2	0.0	-0.2	0.4	1.9	2.3	19.6	7.5
6	0.0	-1.3	0.3	0.0	0.0	0.0	0.3	0.0	-1.3	1.5	1.9	3.4	19.6	4.8
7	-0.2	-1.3	-0.2	0.0	0.0	0.0	-0.1	-0.2	-1.3	1.2	1.9	3.1	19.6	5.3
8	-0.1	-2.0	-0.1	-0.2	0.0	0.0	0.0	-0.1	-2.1	2.0	1.9	3.9	19.6	4.0
9	-0.2	0.0	-0.2	0.0	0.0	0.0	0.0	-0.2	-0.2	0.2	1.9	2.1	19.6	8.3
10	0.1	0.0	0.2	0.0	0.0	0.0	0.2	0.1	0.0	0.2	1.9	2.1	19.6	8.3
11	-0.2	0.0	-0.2	-0.1	0.0	0.0	0.0	-0.2	-0.2	0.2	1.9	2.1	19.6	8.3
12	0.2	-0.3	0.1	-0.1	0.0	0.0	0.2	0.1	-0.3	0.5	1.9	2.4	19.6	7.2
13	-0.1	-1.0	0.0	0.4	0.0	0.0	0.0	0.0	-1.1	1.2	1.9	3.1	19.6	5.3
14	-0.4	-1.6	0.2	0.2	0.0	0.0	0.2	-0.3	-1.6	-1.8	1.9	3.7	19.6	4.3
15	0.0	-1.1	-0.1	0.0	-0.1	0.0	0.0	-0.1	-1.1	1.1	1.9	3.0	19.6	5.5
16	0.0	-1.4	0.0	-0.2	-0.1	0.0	0.0	0.0	-1.4	1.5	1.9	3.4	19.6	4.8

* Allowable at 331°F (maximum temperature for inner shell).

** Based on internal pressure of 50 psi.

Table 2.6.7.1-3 CY-MPC Critical $P_m + P_b$ Stress Summary; 1-ft Top End Drop

Section No.	$P_m + P_b$ Stresses (ksi)						Principal Stresses (ksi)			S.I. Impact (ksi)	S.I. Bolt Preload + Pressure** (ksi)	S.I. Total (ksi)	Allowable Stress* (ksi) $1.5S_m$	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}	S1	S2	S3					
1	0.0	-1.6	0.0	0.0	0.0	0.0	0.0	0.0	-1.6	1.6	1.9	3.5	46.5	11.3
2	0.0	-1.6	0.0	0.0	0.0	0.0	0.0	0.0	-1.6	1.6	1.9	3.6	29.4	7.2
3	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	1.2	1.9	3.1	29.4	8.5
4	0.0	-1.3	0.0	0.0	0.0	0.0	0.0	0.0	-1.3	1.3	1.9	3.2	29.4	8.2
5	0.0	-0.8	0.0	-0.1	0.0	0.0	0.0	0.0	-0.8	0.8	1.9	2.7	29.4	9.9
6	0.0	-1.3	0.3	0.0	0.0	0.0	0.3	0.0	-1.3	1.6	1.9	3.5	29.4	7.4
7	-0.3	-2.2	-0.5	0.0	0.0	-0.1	-0.3	-0.5	-2.2	1.9	1.9	3.8	29.4	6.7
8	0.0	-3.4	-0.4	-0.1	0.0	0.0	0.0	-0.4	-3.4	3.4	1.9	5.3	29.4	4.6
9	-0.9	0.0	-1.0	0.0	0.0	0.0	0.0	-0.9	-1.0	1.0	1.9	2.9	29.4	9.1
10	1.1	0.0	1.2	0.0	0.0	0.0	1.2	1.1	0.0	1.2	1.9	3.1	29.4	8.5
11	-0.6	0.0	-0.1	-0.1	0.0	0.0	0.0	-0.1	-0.6	0.6	1.9	2.5	29.4	10.8
12	0.9	0.1	0.2	0.0	0.0	0.1	0.9	0.2	0.1	0.8	1.9	2.7	29.4	9.9
13	2.9	-0.2	3.1	0.1	0.0	0.0	3.1	2.9	-0.2	3.3	1.9	5.2	29.4	4.7
14	0.5	-1.4	1.2	-0.4	0.2	0.0	1.1	0.5	-1.5	2.7	1.9	4.6	29.4	5.4
15	-0.1	-1.0	0.7	0.2	0.0	0.0	0.7	0.0	-1.1	1.8	1.9	3.7	29.4	7.0
16	2.0	-1.3	1.6	0.0	-0.1	-0.1	2.0	1.6	-1.3	3.3	1.9	5.2	29.4	4.7

* Allowable at 331°F (maximum temperature for inner shell).

** Based on internal pressure of 50 psi.

Table 2.6.7.1-4 CY-MPC Critical P_m Stress Summary; 1-ft Bottom End Drop

Section No.	P_m Stresses (ksi)						Principal Stresses (ksi)			S.I. Impact (ksi)	S.I. Bolt Preload + Pressure** (ksi)	S.I. Total (ksi)	Allowable Stress* (ksi) S_m	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}	S1	S2	S3					
1	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	1.2	1.9	3.1	31.0	9.0
2	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	1.2	1.9	3.1	19.6	5.3
3	0.0	-1.5	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	1.5	1.9	3.4	19.6	4.8
4	-0.2	-1.6	-0.4	-0.1	0.0	0.0	-0.2	-0.4	-1.6	1.4	1.9	3.3	19.6	4.9
5	0.0	-2.5	-0.3	0.3	0.0	0.0	0.0	-0.3	-2.5	2.6	1.9	4.5	19.6	3.4
6	0.0	-1.4	0.3	0.0	0.0	0.0	0.2	0.0	-1.4	1.6	1.9	3.5	19.6	4.6
7	0.0	-0.8	0.4	0.1	0.0	0.0	0.4	0.0	-0.8	1.1	1.9	3.0	19.6	5.5
8	0.0	-0.6	0.4	-0.2	0.0	0.0	0.4	0.0	-0.6	1.0	1.9	2.9	19.6	5.8
9	-0.5	-2.0	-0.2	-0.6	0.1	0.0	-0.2	-0.3	-2.2	2.1	1.9	4.0	19.6	3.9
10	0.3	-1.0	0.3	-0.3	0.0	0.0	0.3	0.3	-1.1	1.4	1.9	3.3	19.6	4.9
11	-0.3	-1.9	-0.4	0.0	0.3	0.0	-0.3	-0.3	-1.29	1.6	1.9	3.5	19.6	4.6
12	0.4	-0.7	0.4	0.1	0.0	0.0	0.4	0.4	-0.7	1.1	1.9	3.0	19.6	5.5
13	-0.1	-0.1	-0.1	0.1	0.0	0.0	0.0	-0.1	-0.1	0.1	1.9	2.0	19.6	8.8
14	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	0.1	1.9	2.0	19.6	8.8
15	-0.1	-0.3	-0.1	0.2	0.0	0.0	0.0	-0.1	-0.4	0.4	1.9	2.3	19.6	7.5
16	0.0	-0.1	0.0	0.1	0.0	0.0	0.0	0.0	-0.1	0.1	1.9	2.0	19.6	8.8

* Allowable at 331°F (maximum temperature for inner shell).

** Based on internal pressure of 50 psi.

Table 2.6.7.1-5 CY-MPC Critical $P_m + P_b$ Stress Summary; 1-ft Bottom End Drop

Section No.	$P_m + P_b$ Stresses (ksi)						Principal Stresses (ksi)			S.I. Impact (ksi)	S.I. Bolt Preload + Pressure** (ksi)	S.I. Total (ksi)	Allowable Stress* (ksi) $1.5S_m$	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}	S1	S2	S3					
1	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	1.2	1.9	3.1	46.5	14.0
2	0.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	-1.2	1.2	1.9	3.1	29.4	8.5
3	0.0	-1.5	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	1.5	1.9	3.4	29.4	7.6
4	-0.4	-2.6	-0.8	-0.1	0.0	-0.1	-0.4	-0.8	-2.6	2.2	1.9	3.1	29.4	8.5
5	0.1	-4.6	-0.8	0.1	0.0	0.0	0.1	-0.8	-4.6	0.8	1.9	2.7	29.4	9.9
6	0.0	-1.4	0.2	0.0	0.0	0.0	0.2	0.0	-1.4	1.6	1.9	3.5	29.4	7.4
7	0.0	-1.0	0.3	0.0	0.0	0.0	0.3	0.0	-1.0	1.3	1.9	3.2	29.4	8.2
8	0.0	-1.2	0.2	0.1	0.0	0.0	0.2	0.0	-1.3	1.5	1.9	3.4	29.4	7.7
9	1.3	-1.3	2.1	-0.4	0.0	0.0	2.1	1.4	-1.3	3.4	1.9	5.3	29.4	4.5
10	3.3	-0.4	3.8	-0.2	0.0	0.0	3.8	3.3	-0.4	4.2	1.9	6.1	29.4	3.8
11	1.5	-1.3	1.4	-0.3	0.2	-0.1	1.6	1.3	-1.3	2.9	1.9	4.8	29.4	5.1
12	1.3	-0.6	0.9	0.2	0.0	0.0	1.3	0.9	-0.6	1.9	1.9	3.8	29.4	6.7
13	1.7	0.1	1.8	0.0	0.0	0.0	1.8	1.7	0.1	1.7	1.9	3.6	29.4	7.2
14	1.0	-0.1	1.1	0.0	0.0	0.0	1.1	0.1	-1.1	1.1	1.9	3.0	29.4	8.8
15	-0.2	-0.4	0.5	0.2	0.0	0.0	0.5	0.0	-0.5	1.1	1.9	3.0	29.4	8.8
16	-0.1	-0.1	0.4	0.1	0.0	0.0	0.4	0.0	-0.2	0.5	1.9	2.4	29.4	11.3

* Allowable at 331°F (maximum temperature for inner shell).

** Based on internal pressure of 50 psi.

THIS PAGE INTENTIONALLY LEFT BLANK

2.6.7.2 One-Foot Side Drop

The NAC-STC is structurally evaluated for the normal conditions of transport 1-foot side drop in accordance with the requirements of 10 CFR 71.71. In this event, the NAC-STC (equipped with an impact limiter over each end) falls through a distance of 1 foot onto a flat, unyielding, horizontal surface. The cask strikes the surface in a horizontal position; consequently, a side impact on the cask occurs. The types of loading involved in a side drop accident are closure lid bolt preload, internal pressure, thermal, impact load, and inertial body load. There are three credible side impact conditions to be considered, according to Regulatory Guide 7.8:

1. Side drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.
2. Side drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.
3. Side drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

During a side drop impact event, the cask body experiences a lateral deceleration. Considering the cask as a free body, the impact limiters apply the load to the side of the cask (in the impact limiter contact area) to produce the deceleration. Since the deceleration represents an amplification factor for the inertial loading of the cask, the equivalent static method is adopted to perform the impact evaluations. The analyses consider the behavior of the cask to be linearly elastic. Additionally, fabrication stresses are considered to be negligible (Section 2.6.11).

2.6.7.2.1 One-Foot Side Drop Evaluation of the NAC-STC Cask in the Directly Loaded and Yankee-MPC Canistered Fuel Configurations

The finite element analysis method is utilized to perform the side drop stress evaluations for the NAC-STC. The 1-foot side drop condition is analyzed using a three-dimensional structural model to accurately represent the non-axisymmetric loads involved in the side drop case. One-half of the cask is modeled as a three-dimensional structure with one plane of symmetry. The ANSYS STIF45 three-dimensional solid element is the primary element type used in the model.

In order to reduce the overall problem of size to satisfy the limitations of the ANSYS program and the computer hardware, two three-dimensional models have been constructed for the directly loaded fuel configuration—the top fine mesh model and the bottom fine mesh model. A single

three-dimensional finite element model is constructed and used for the Yankee-MPC canistered fuel configuration of the NAC-STC. A detailed description of the three-dimensional finite element models of the NAC-STC is presented in Section 2.10.2.1.2 for each of the fuel configurations. The top fine mesh model contains a fine mesh region at the upper half of the cask with a relatively coarse mesh at the bottom end; the bottom fine mesh model contains a fine mesh region at the bottom end of the cask with relatively coarse mesh at the top end. Nevertheless, both models are complete representations of the cask, since the entire cask is modeled. Both models are used in the side drop analyses to obtain the detailed stresses at each end of the cask. The stress results from the fine mesh portion of each model are then combined to provide a final stress summary for the NAC-STC for the 1-foot side drop condition for the directly loaded fuel configuration. For the canistered fuel configuration, the stress results are obtained from the single finite element model of the NAC-STC for the Yankee-MPC configuration.

Five categories of load—closure lid bolt preload, internal pressure, thermal, impact, and body inertia—are considered on the cask:

1. Closure lid bolt preload - The required bolt preloads on the inner lid and outer lid are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3. The bolts are modeled as beam (ANSYS STIF4) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. Pressures of 50 psig and 12 psig are applied on the interior surfaces of the cask cavity for the hot ambient and cold ambient cases, respectively. These pressures envelope the calculated pressures for all cask configurations—directly loaded fuel (12 psig), canistered fuel (11.3 psig), and canistered GTCC waste (< 11.3 psig).

3. Thermal - The heat transfer analyses performed in Sections 3.4.2 and 3.4.3 determine the cask temperature distributions for the following three combinations of ambient temperature, heat load, and solar insolation for directly loaded fuel:

   Condition 1. 100°F ambient temperature, with maximum decay heat load and maximum solar insolation.

   Condition 2. -20°F ambient temperature, with maximum decay heat load, and no solar insolation.

$S_{br\text{-}1g}$ = 56,000/(0.5 x 31 x 3.14 x 71.0 x 0.25)
= 64.8 psi

For the 18.1 g 1-foot drop the maximum bearing stress in the cavity wall is:

$S_{br\text{-}18.1g}$ = (18.1)(64.8) = 1,170 psi

Using an allowable based on the maximum inner shell temperature, 1.5 S_y = 32.94 ksi at 331°F, the margin of safety is:

MS = 32.94/1.17 - 1 = +Large

The bearing stress on the cask cavity wall for the Yankee-MPC fuel configuration is lower than that for the directly loaded fuel configuration because the support disk loads bear directly on the canister shell, which increases the bearing region on the cask cavity wall and reduces the bearing stresses. This condition is also true for the Yankee-MPC GTCC waste configuration.

2.6.7.2.2 One-Foot Side Drop Evaluation for the CY-MPC Configuration

The NAC-STC cask with the CY-MPC canistered configuration is modeled as a three-dimensional structure using ANSYS STIF45 isoparametric elements. A detailed description of the three-dimensional finite element model of the NAC-STC cask body for the canistered configurations is provided in Section 2.10.2.1.3. The model used in this evaluation is also used for the 1-foot end drop evaluation.

Five categories of loads are considered in this evaluation: closure lid bolt preload, internal pressure, thermal expansion, impact and inertial loading:

1. Closure lid bolt preload - The required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. The principal stresses corresponding to the bolt preload with a 50 psig internal pressure for the directly loaded configuration are reported in Table 2.10.4-1 and the maximum stress intensity is 1.9 ksi (Location U3). To account for the preload and internal pressure for the CY configuration, the 1.9 ksi is added to the stresses due to the 1-foot end drop.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. A pressure of 50 psig, which enveloped the calculated pressure of 38.1 psig for this configuration, is effectively used by adding the 1.9 ksi (reported above for the bolt preload) to the stresses due to the 1-foot end drop.
3. Thermal - The ANSYS analysis determines the stresses arising from the thermal expansion of the cask from its initial 70°F condition, including the effects of the differential thermal growth within the components, which is a result of the temperature difference across the walls of the cask. The cask temperature distributions are also used in the ANSYS structural analyses to determine the values of the temperature-dependent material properties. Heat transfer analyses performed in Sections 3.4.2 and 3.4.3 determine the cask temperature distributions for the following two conditions for the canistered fuel configuration (an analysis for the third condition is not required):

    1. 100°F ambient temperature, maximum decay heat load (17 kW).
    2. -40°F ambient temperature, maximum decay heat load (17 kW), and no solar insolation.
    3. -40°F ambient temperature, no decay heat load, and no solar insolation.

    To bound the stresses arising from thermal expansion, the maximum stress intensity (8.1 ksi, location G5) from Table 2.10.4-5, is added to the maximum stress intensity in the side drop evaluation. The maximum thermal stress intensity is associated with Thermal Condition 1. To ensure that the minimum stress allowable is used, the allowables are taken at the maximum temperature of the inner shell (331°F) for Thermal Condition 1. The temperature distribution for the canistered CY GTCC waste is considered to be enveloped by the 17 kW design basis heat load. Individual thermal cases are not evaluated since the design basis heat load of 22.1 kW for the directly loaded fuel envelops the 17 kW basis heat load for the CY-MPC configuration.

4. Impact loads - The impact loads are induced by the impact limiter acting on the sides of the cask top end forging and bottom end forging during a side drop condition. The impact loads are determined from the energy absorbing characteristics of the impact limiters, and the impact load is expressed in terms of the design cask weight (loaded or empty), multiplied by appropriate deceleration factors (g).

    Instead of representing the impact load as a pressure applied to the sides of the cask body, the impact limiter load is represented by the contact force generated by the gap elements

model is a complete representation of the cask. There is a fine mesh region at the impacting end of the cask with a relatively coarse mesh at the opposite end of the cask. The maximum stresses occur at the impacting end of the cask; therefore, the fine element mesh density is used in this region to provide accurate results. The stresses calculated using the coarse element mesh at the non-impacting end of the model are an accurate representation of the stresses present there; however, the maximum stresses occur in that end of the cask for the load condition, in which it is the impacting end of the cask. The detailed descriptions of the three-dimensional finite element models of the NAC-STC are described in Section 2.10.2.1.2.

During a corner impact event, the impact limiter will apply the load to the cask impacting corner to produce the deceleration. Since the deceleration represents an amplification factor for the inertial loading of the cask, the equivalent static method is adopted to perform the impact evaluations. Additionally, the fabrication stresses are considered to be negligible (Section 2.6.11).

Five categories of load—closure lid bolt preload, internal pressure, thermal, impact, and body inertia—are considered on the cask:

1. Closure lid bolt preload - The required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3. The bolts are modeled as beam (ANSYS STIF4) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. Pressures of 50 psig and 12 psig are applied on the interior surfaces of the cask cavity for the hot ambient and cold ambient cases, respectively. These pressures envelope the calculated pressures for all cask configurations—directly loaded fuel (12 psig), canistered fuel (11.3 psig), and canistered GTCC waste (< 11.3 psig).

3. Thermal - The heat transfer analyses performed in Sections 3.4.2 and 3.4.3 determine the cask temperature distributions for the following three combinations of ambient temperature, heat load, and solar insolation for directly loaded fuel:

   Condition 1: 100°F ambient temperature, with maximum decay heat load, and maximum solar insolation.

Condition 2: -20°F ambient temperature, with maximum decay heat load and no solar insolation.

Condition 3: -20°F ambient temperature, with no decay heat load, and no solar insolation.

The cask temperature distributions calculated for each of these three thermal conditions are used as inputs to the ANSYS structural analyses for the directly loaded fuel configuration. The ANSYS analysis determines the stresses induced by the thermal expansion of the cask from its initial 70°F condition. The cask temperature distributions are also used in the ANSYS structural analyses to determine the values of the temperature-dependent material properties, such as modulus of elasticity, density, and Poisson's ratio.

4. Impact loads - The impact loads are produced by the impact limiter acting on the cask end during a corner drop condition. The impact loads are determined from the energy absorbing characteristics of the impact limiters, as described in Section 2.6.7.4. The impact load is expressed in terms of the design cask weight (loaded or empty), multiplied by an appropriate deceleration factor (g). A design deceleration factor of 20 g is used for both top and bottom corner drops. This compares to the actual deceleration factor of 5.3 g, as documented in Section 2.6.7.4, Table 2.6.7.4.1-3.

The impact loads for the corner drop analyses have lateral and longitudinal components, which are calculated from the total impact load. The lateral load component is applied along the circumferential direction using a cosine-shaped distribution similar to that used in the side drop analysis (over a 0° to 79.4° arc on each side of the impact centerline). The longitudinal load component is applied using an uniform distribution on the end surface of the impacting end of the cask, over the same 0- to 79.4-degree arc on each side of the impact centerline.

Section 2.10.2.2.2 documents the calculation of the impact pressures for the NAC-STC design weight of 250,000 pounds and an impact limiter contact length of 24.06 inches (12.03 inches at each end). For the corner drop, the impact energy is absorbed by only one impact limiter; hence, the corner drop lateral impact pressures may be calculated by

2.6.7.4 Impact Limiters

Removable transport impact limiters are included in the NAC-STC design to ensure that the design impact loads on the cask are not exceeded for any of the defined impact load conditions. The defined loading conditions include the cask falling 1 foot or 30 feet and landing either on its side, impacting both impact limiters simultaneously, or vertically on one impact limiter at either end. As discussed in Section 2.10.7, the oblique impact events are bounded by the end and/or side drop events, as there is no "slap down" effect exhibited by the cask. Consequently, oblique drops and oblique drop angles are not evaluated.

Two impact limiter configurations are used. The first configuration, described in Section 2.6.7.4.1, is primarily redwood with a small amount of balsa wood (redwood impact limiter). The wood is encased in a stainless steel shell. The balsa wood is limited to the outer corner edges of the impact limiter for use in the corner drop orientations. These impact limiters may be used only with the directly loaded fuel and Yankee-MPC canistered fuel and GTCC waste cask contents. The second configuration, described in Section 2.6.7.4.2, is primarily balsa wood with a limited amount of redwood (balsa impact limiter). The wood is also encased in a stainless steel shell. This configuration may be used with the directly loaded fuel, Yankee-MPC fuel or GTCC waste or the CY-MPC fuel or GTCC waste cask contents.

2.6.7.4.1 Redwood Impact Limiter Evaluation

The package geometry, package weight, contents weight, and package center of gravity location are the parameters that control the impact limiter design. The impact limiter evaluation presented in this section is for the package (loaded NAC-STC cask with impact limiters, as described on the drawings in Section 1.3.2) with a total weight of 250,000 pounds, a center of gravity located 96.01 inches above the bottom outer surface of the cask body, and a cavity contents weight of 56,000 pounds. This evaluation envelops the NAC-STC cask directly loaded fuel and the Yankee-MPC canistered fuel and GTCC waste configurations. The package geometry is approximately identical for all of the configurations, as is the package center of gravity location. Axial spacers have been designed for the cask cavity to locate the Yankee-MPC canister loaded with fuel or GTCC waste such that the package center of gravity location is

approximately identical to that of the directly loaded fuel configuration. The differences in the contents weight and the associated package weight for each of the contents configurations—56,000 pounds and 249,700 pounds for directly loaded fuel, 55,590 pounds and 249,290 pounds for the Yankee-MPC fuel, and 54,271 pounds and 247,971 pounds for the Yankee-MPC GTCC waste—have no significant effect on the impact limiter design or performance. Therefore, the impact limiter analysis in this section, the cask drop analyses in Sections 2.6.7 and 2.7.1, and the scale model tests and results in Section 2.10.6 are applicable for the directly loaded and the Yankee-MPC canistered configurations of the NAC-STC.

Assumptions

The following assumptions form the basis for the transport impact limiter analysis:

1. The cask impacts on an unyielding surface.

2. The impact limiter remains in position on the cask during all impact events (The qualification of the impact limiter attachment is presented in Section 2.6.7.4.7.).

Load Conditions

The transport impact limiters described and analyzed in the following paragraphs decelerate the cask by applying a force in the direction opposite the motion of the cask. The deceleration force is generated by crushing the redwood and balsa wood materials of the impact limiter between the cask and the unyielding surface. The energy absorbed during crushing is the net force, the vector sum of the cask weight (downward) and the deceleration force (upward), multiplied by the distance crushed. The amount of energy an impact limiter can absorb is calculated for various cask impact orientations, from vertical (0°) to horizontal (90°).

The specific loading conditions for the transport impact limiters are defined by 10 CFR 71.71(c)(7), 10 CFR 71.73(c)(1) and Regulatory Guide 7.8, as follows:

1. A 1-foot drop of the cask impacting at any angle from vertical (flat end) to corner (cask center of gravity is directly above the point of impact).

2. A 1-foot drop of the cask in a horizontal orientation.

3. A 30-foot drop of the cask in an end, a side, or an oblique orientation.

2.6.7.4.2 Balsa Impact Limiters

The balsa impact limiter evaluation presented in this section is for all cask configurations, i.e., NAC-STC directly loaded fuel configuration, the Yankee-MPC and CY-MPC canistered fuel configurations, or the Yankee-MPC and CY-MPC canistered GTCC waste configurations, with a total package weight with impact limiters attached not exceeding 260,000 pounds.

The package geometry is similar for all of the configurations. Axial spacers are designed for the cask cavity to locate the canister loaded with fuel or GTCC waste such that the package center of gravity location is approximately the same as that of the directly loaded fuel configuration.

Differences in contents weight and the weights of the associated package configurations have no significant effect on the balsa impact limiter design or performance. Therefore, the balsa impact limiter analysis in this section and the cask drop analyses in Sections 2.6.7 and 2.7.1 are applicable for all contents configurations of the NAC-STC, Yankee-MPC, and CY-MPC.

2.6.7.4.2.1 Assumptions

The following assumptions form the basis for the balsa impact limiter analysis:

1. The cask impacts on an unyielding surface.
2. The balsa impact limiter remains in position on the cask during all impact events. (The qualification of the balsa impact limiter attachment is presented in Section 2.6.7.4.2.7.)

2.6.7.4.2.2 Load Conditions

The balsa impact limiters described and analyzed in the following paragraphs decelerate the cask by applying a force in the direction opposite the motion of the cask. Crushing the balsa wood and redwood materials, the stainless steel gussets, and stainless steel shells of the balsa impact limiter between the cask and the unyielding surface generates the deceleration force.

The specific loading conditions for the transport Balsa lightweight impact limiters are defined by 10 CFR 71.71(c)(7), 10 CFR 71.73(c)(1) and Regulatory Guide 7.8, as follows:

1. A 1-foot drop of the cask impacting at any angle from vertical (flat end) to corner (cask center of gravity is directly above the point of impact).
2. A 1-foot drop of the cask in a horizontal orientation position.
3. A 30-foot drop of the cask in an end, a side and an oblique orientation.

Based on these loading conditions, the NAC-STC balsa impact limiters are primarily designed for the 30-foot cask drops but with consideration of the 1-foot end, side and corner drops. The maximum impact forces and the maximum crush depth for the 1-foot and 30-foot cask drops are obtained from the LS-DYNA analyses of the balsa impact limiters. LS-DYNA is an explicit finite element program for the nonlinear dynamic analysis of three-dimensional structures (Section 2.10.1.3).

2.6.7.4.2.3 Description—Balsa Impact limiters

Figures 2.6.7.4.2-1 and 2.6.7.4.2-2 show the primary dimensions of the balsa impact limiters. Figure 2.6.7.4.2-2 shows the cross-section of a balsa impact limiter. Except for the pockets for the lifting trunnions in the upper limiter, the upper and lower balsa impact limiters are identical.

Each balsa impact limiter includes both balsa and redwood for energy absorption. The grain direction of the wood is oriented to achieve the desired crush strength. The balsa and redwood is enclosed in a stainless steel shell to protect and maintain its position and orientation. Stainless steel gussets are arranged in 15-degree increments to maintain the orientation of the wood during the side drop.

2.6.7.4.2.4 Properties of Balsa Wood and Redwood

The balsa wood to be used in the NAC-STC balsa impact limiter is specified to have a density between 7 and 10 pounds per cubic foot and to have a moisture content between 5 and 15 percent for any one piece with an average moisture content of not more than 12 percent for any lot. A density limit of 7 to 10 pounds/cubic foot is applied to be consistent with dynamic wood test density criteria.

To adequately specify the balsa crush strength, NAC conducted dynamic compression tests of specimens taken from balsa obtained from a commercial supplier. The average density of the balsa wood tested was 8.5 lbs/ft^3 (8.5 $\pm$ 1.5 lbs/ft^3). To ensure an adequate sampling, the following matrix was developed to test a series of specimens at various strain rates:

crush. Test specimens are fabricated from larger wood boards having specified material properties for moisture content and density. Wood test specimen size was based on test machine requirements.

For each strain rate and temperature condition, a data set was created that consists of 10 to 15 individual test specimens. To reduce this data, individual files of a data set were averaged together. These average curves were then simplified using minimal (30) data points. To produce simplified curves, the peak acceleration was retained and the area under the curve that represents the energy absorption capacity was maintained. Stress-strain curves are developed in the parallel and perpendicular-to-the-grain directions for hot (200°F) and cold (-40°F) conditions. Table 2.6.7.4.2-1 and Table 2.6.7.4.2-2 provide a summary of the data used in the LS-DYNA analyses.

2.6.7.4.2.5 Balsa Impact Limiter Finite Element Model

The balsa impact limiter finite element model was built using the ANSYS pre-processor and LS-DYNA's Finite Element Model Builder. The impact analyses were performed using LS-DYNA. The model is constructed of 8-node brick and 4-node shell elements. A full half model of the impact limiters and cask was generated. The LS-DYNA model is shown in Figure 2.6.7.4.2-3.

Boundary Conditions and Initial Conditions

LS-DYNA "Surface_to_Surface" contact interface is employed between each part in the impact limiter and between the cask body and impact limiter shells. The model sits on a rigid plane ("Rigidwall_Geometric_Flat"). Symmetry boundary conditions are imposed on the nodes in the X-Z plane for all drop conditions. For the corner drop cases, the model is rotated so that the X-axis aligned in impact direction. The weight of the canister lids is included in the content weight and is distributed over the length of the cavity by varying the density of the elements in the different regions of the model. The weight and CG of the finite element model correspond to those of the NAC-STC cask. Therefore, the interaction between the cask body and impact limiters is correctly modeled.

To simulate a rigid cask body, all nodes of the cask shell elements were constrained. To achieve a total weight of 260,000 pounds, the density of the material representing the cask body was increased. The total weight was verified by checking the total kinetic energy of the quarter

model. An initial velocity of 96.3 in./sec and 527.4 in./sec was applied to the entire model to represent the 1-foot and 30-foot drops, respectively.

To bound the extreme temperature conditions and maximize accelerations and crush, cold (-40°F) and hot (200°F) analyses are performed for accident conditions. However, since the amount of crush is small during the 1-ft drop, cold balsa properties are used to maximize accelerations for normal conditions.

The drop orientations considered in the evaluation of the balsa impact limiter are shown in Figure 2.6.7.4.2-4. The top and bottom impact limiters are identical except for the trunnion pocket in the upper impact limiter. Since the trunnion provides additional backed area that may contribute to the total acceleration, the upper impact limiter is used to evaluate the end and corner impact conditions. For the side drop, the cask is dropped on the trunnion side of the impact limiter. This is conservative since less crush capacity is available during the hot conditions side drop.

Material Properties

To account for gross deformation and buckling, the Type 304 stainless steel shells and gussets were modeled with an elasto-plastic material. The LS-DYNA material Type 24 was used ("Piecewise_Linear_Plasticity"). The required input data is:

Steel Shell Property	Value
Mass Density, ρ	7.51E-04 lb-sec^2/in^4
Modulus of Elasticity, E	27.9E6 psi
Poisson's Ratio, ν	0.30

The stress-strain curve used for Type 304 stainless steel is:

STRESS (psi)	STRAIN (in/in)
23,809	0.000041
28,033	0.001180
29,500	0.003180
31,970	0.007180
36,900	0.015100
42,300	0.039200
85,080	0.230000

An elastic material model with the following properties was used to represent the NAC-STC cask body as shown in Figure 2.6.7.4.2-3.

NAC-STC Cask Body Properties	Value
Modulus of Elasticity, E	1.0E7 psi
Poisson's Ratio, ν	0.30

The NAC-STC cask body model consists of a single shell using an elastic material. The elastic modulus of the cask body was adjusted to allow the cross-sectional modulus of the finite element model to be equal to that of the full-scale cask. The mass density of the cask was also adjusted to ensure that the total kinetic energy is accounted for. Therefore, the mass density varies slightly depending on the drop orientation.

To account for the strain-rate sensitivity of the wood, the LS-DYNA analyses use material 163 (modified_crushable_foam). The modified_crushable_foam material model allows for the input of several stress-strain curves of various strain-rates. Up to three stress-strain curves are used ranging from 0 ε/sec to 175 ε/sec. For each time step during an analysis, LS-DYNA calculates the strain-rate of an individual element and uses the stress-strain data from the inputted stress-strain curves. For a strain rate between the inputted curves, LS-DYNA interpolated between the given curves. For low velocity impacts such as the 1-ft side drop, strain rates are essentially static. Therefore, LS-DYNA interpolates between the static stress-strain curve and the second stress-strain curve in the series. To account for crush strength fabrication tolerances, the -40°F cold case comparison stresses are factored by 1.10 and the +200°F hot case compression stresses are factored by 0.90.

The wood impact limiter surrounding the cask consists of 24 equally spaced angular wedges separated by radial gussets fabricated from steel plates. Since a half-symmetry finite element model is used to represent the impact limiters, only 12 of the wood wedges are modeled. Out of the 12 modeled wood wedges, only 3 wedges are loaded during a 30 foot side drop. The first wedge is loaded in the parallel to grain direction. The second and third wedges are loaded between the parallel and perpendicular to grain directions. For the wedges where the impact force is applied between the parallel and perpendicular to grain directions, Hankinson's formula (Baumeister, page 6-127) is used to vary the strength properties of wood with the orthotropic axes of the wood grain.

$$N = \frac{PQ}{P\sin^2\theta + Q\cos^2\theta}$$

where:

N = stress induced by a load acting at an angle to the grain direction,
P = stress parallel to the grain direction,
Q = stress perpendicular to the grain direction,
θ = angle between direction of load and grain direction.

Using Hankinson's formula, stress-strain curves are generated for the second and third wedges at 15 and 30 degrees, respectively. Therefore, in the LS-DYNA input files, unique stress-strain curves are applied to each wood wedge depending on the loading angle and strain rate.

2.6.7.4.2.6 Results

To obtain results from LS-DYNA, nodes of interest are used to record output data. The output is in the form of displacement and acceleration time histories. However, the acceleration time histories contain high frequency components that are induced by the model's interior geometry but do not represent a global response to the external impact. Therefore, the time histories have to be filtered to obtain true accelerations corresponding to the global response. For this evaluation, the Butterworth low-pass filter in LS-DYNA's post-processor is used with a filter at 100 Hz. Figures 2.6.7.4.2-5 through 2.6.7.4.2-10 provide the filtered acceleration time-history curves for the normal and accident conditions drop analyses.

Evaluation of the balsa impact limiter for the normal conditions of transport shows that a maximum acceleration of 16.5g occurs during the side drop. Table 2.6.7.4.2-3 summarizes the accelerations for the three normal condition cases considered. In each case, the calculated acceleration is less than the design acceleration of 20g.

For accident conditions, the maximum acceleration of 48.5g also occurs during the cold condition side drop aligned with the trunnion. During the end drop, the maximum acceleration of 40.8g occurs during hot conditions. The dynamic load factor (DLF) is calculated by performing a modal analysis on the basket support and applying the acceleration time histories from the side and end drops. The DLF calculated for the side and end drops is 1.02 and 1.00, respectively. Since the side and end drops bound the corner drop acceleration, the DLF is not reported for the corner drop acceleration.

Table 2.6.7.4.2-4 summarizes the accelerations for the three hot and cold accident cases considered. In each case, the calculated acceleration is less than the design acceleration of 55g for the side drop and 48g for the end and corner drops. As Table 2.6.7.4.2-2 shows, the maximum strain of 72% occurs during the hot condition side drop at the trunnion. The high strain below the trunnion is considered a localized phenomenon. Strain outside of the trunnion region is less than 50%. Therefore, lock-up of the balsa wood does not occur.

2.6.7.4.2.7 Balsa Impact Limiter Attachment Analysis

Each balsa impact limiter is approximately 3,000 pounds lighter than the redwood impact limiter (refer to Tables 2.2-1 and 2.2-4). Due to the difference in contour of the outside surface, the balsa wood impact limiter uses shorter retaining rods than those used with the redwood impact limiter. Both designs use 16 stainless steel retaining rods, each 1-inch in diameter, equally spaced on a 76.0-inch diameter bolt circle and share the same interior dimensions and cask interface. The balsa impact limiter retaining rods are fabricated from high strength ASTM SA-193 grade B8S stainless steel, which has yield and ultimate strengths of 50 ksi and 95 ksi, respectively. This material is higher strength and more ductile than the retaining rods used with the redwood impact limiters. The retaining rods for the redwood impact limiters are SA-276, Type 304 stainless steel, having yield and ultimate strengths of 30 ksi and 75 ksi, respectively. Therefore, the redwood impact limiter attachment evaluation presented in Section 2.6.7.4.1.4, bounds the balsa impact limiter attachment design.

Figure 2.6.7.4.2-1 Three-Dimensional View of the Balsa Impact Limiter

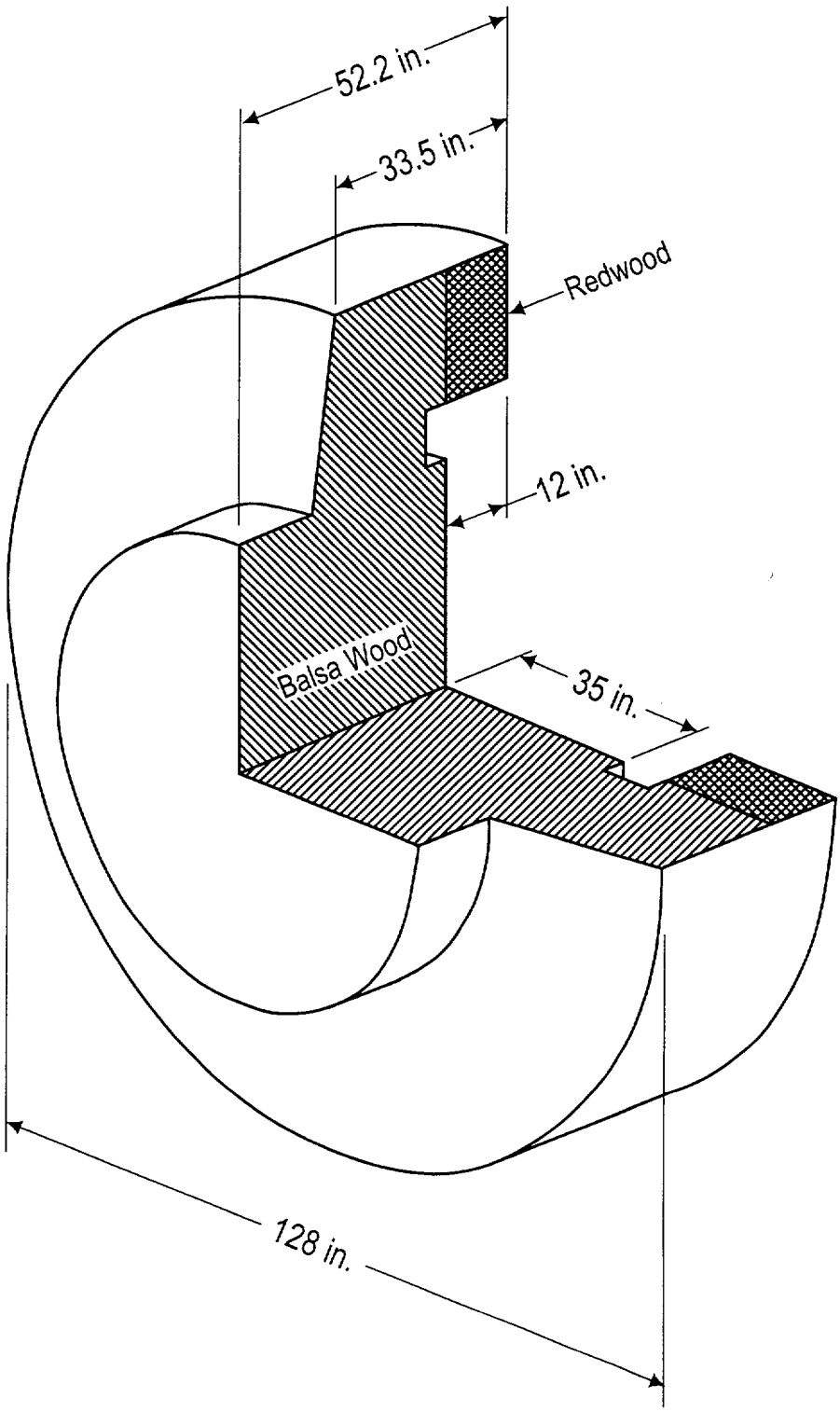


Figure 2.6.7.4.2-10 Acceleration Time-History for 30-ft Drop onto Corner (Hot and Cold Conditions)

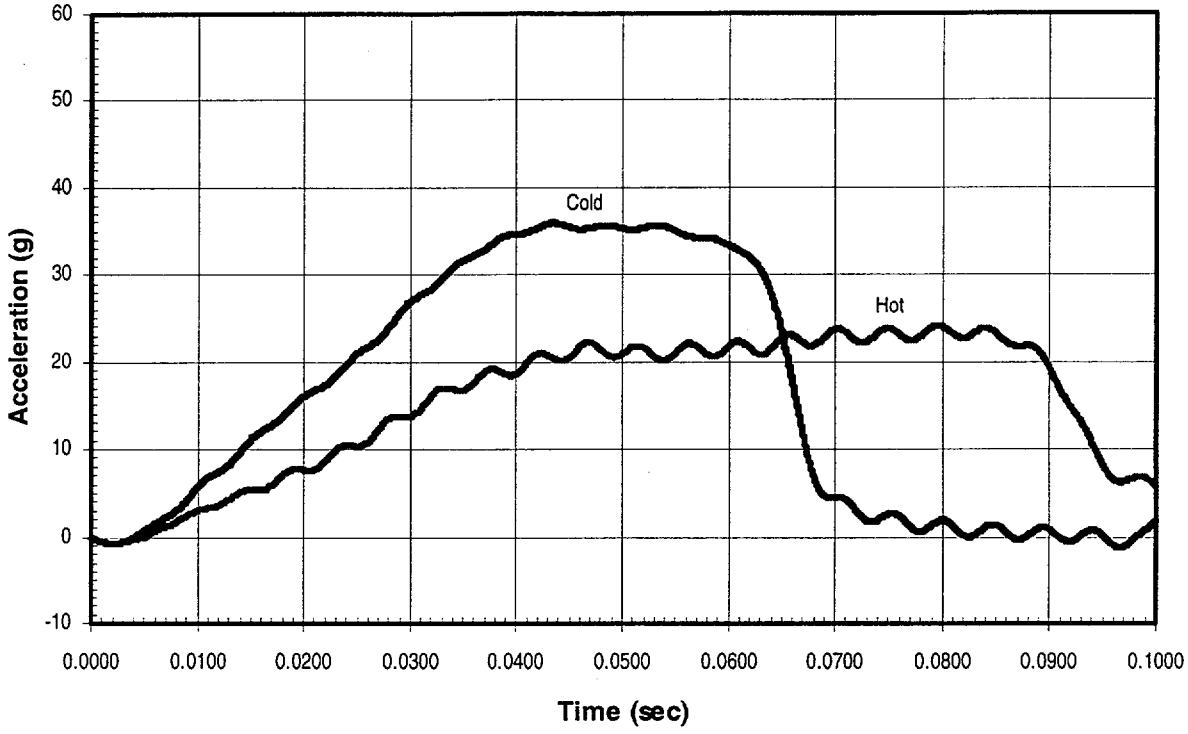


Table 2.6.7.4.2-1 Redwood Stress-Strain Properties

Strain (in/in)	Parallel to Grain—Stress (psi)			
	Hot Static	Hot 25 ε/sec	Cold Static	Cold 25 ε/sec
0.000	0	0	0	0
0.100	3736	5859	9294	8506
0.400	3685	4996	8531	10734
0.700	10004	15458	22085	19683

Strain (in/in)	Perpendicular to Grain—Stress (psi)			
	Hot Static	Hot 25 ε/sec	Cold Static	Cold 25 ε/sec
0.000	0	0	0	0
0.100	542	968	1396	1629
0.400	849	1363	2054	2608
0.700	7433	13553	17631	19017

Table 2.6.7.4.2-2 Balsa Wood Stress-Strain Properties

Strain (in/in)	Parallel to Grain—Stress (psi)			
	Hot Static	Hot 25 ε/sec	Cold Static	Cold 25 ε/sec
0.000	0	0	0	0
0.100	1724	1385	2306	2546
0.400	1550	1150	2073	2805
0.700	1550	1040	2073	2370

Strain (in/in)	Perpendicular to Grain—Stress (psi)			
	Hot Static	Hot 25 ε/sec	Cold Static	Cold 25 ε/sec
0.000	0	0	0	0
0.100	121	105	161	215
0.400	109	144	145	293
0.700	109	300	145	611

Table 2.6.7.4.2-3 Summary of Results for the Balsa Impact Limiter Normal Conditions of Transport Drop Analysis

Drop Orientation	Cold Condition (-40°F)	
	Normal Acceleration (g)	Design Acceleration (g)
Side	16.5	20.0
Top/Bottom End	14.5	20.0
c.g. over Corner	5.6	20.0

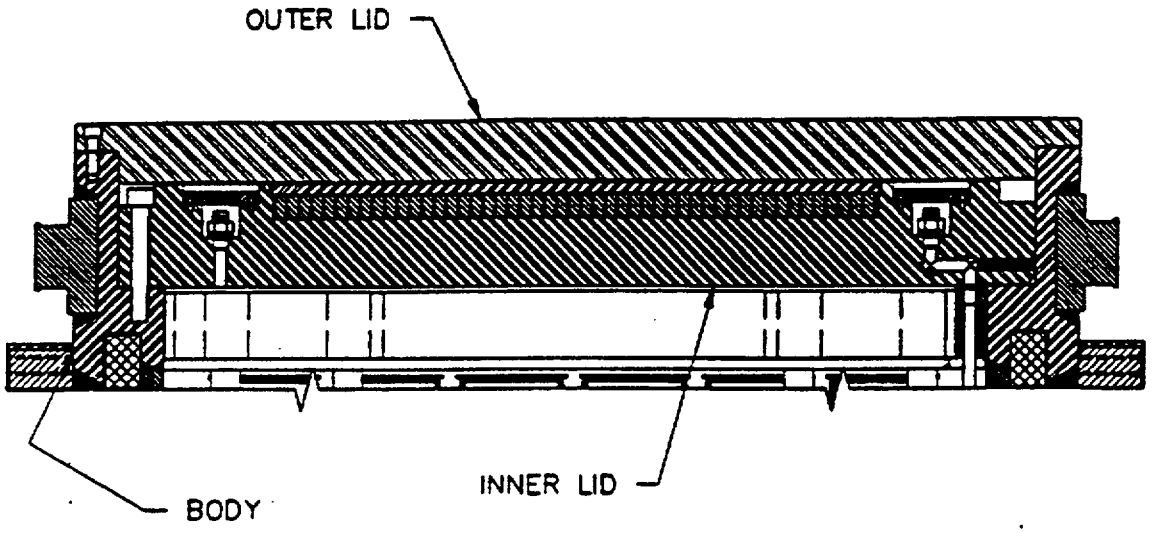
Table 2.6.7.4.2-4 Summary of Results for the Balsa Impact Limiter Hypothetical Accident Conditions Drop Analysis

Drop Orientation	Hot Condition (200°F)			Cold Condition (-40°F)			Maximum Acceleration × DLF	Design Acceleration (g)
	Accident Acceleration (g)	Crush Depth (in.)	Percent Strain	Accident Acceleration (g)	Crush Depth (in.)	Percent Strain		
Side	42.9	12.8	72%	48.5	11.9	70%	49.5	55.0
Top/Bottom End	40.8	21.0	55%	39.9	12.5	33%	40.8	48.0
c.g. over Corner	24.2	29.2	66%	36.0	21.1	48%	—	48.0

THIS PAGE INTENTIONALLY LEFT BLANK

2.6.7.5 Closure Analysis - Normal Conditions of Transport

The main closure of the NAC-STC is effected by an assembly of a bolted inner lid and a bolted outer lid. The Type 304 stainless steel inner lid is bolted to the top forging by forty-two 1 1/2 - 8 UN bolts fabricated from SB-637, Grade N07718 nickel alloy bolting material and is sealed by two metallic o-rings. The SA-705, Type 630, 17-4 PH stainless steel outer lid is bolted to the end of the top forging by thirty-six 1 - 8 UNC bolts fabricated from SA-564, Type 630, 17-4 PH stainless steel, and is sealed to the top forging by one metallic o-ring.



Closure Assembly of NAC-STC Body and Lids

2.6.7.5.1 Closure Geometry

The main body of the inner lid is 9.0 inches thick and 79.0 inches in diameter. A 3.0-inch thick, 2.75-inch wide integral outer rim on the top of the inner lid encloses a 2.0-inch thick layer of NS-4-FR neutron shielding material and a 1.0-inch thick, Type 304 stainless steel coverplate. The inner lid provides the primary containment for the NAC-STC main closure.

The outer lid is a plate consisting of a 5.25-inch thick central body having a 79.08-inch diameter and a 2.50-inch thick integral outer flange having an outside diameter of 86.70 inches. There is a 0.06-inch gap between the inner lid and the outer lid.

2.6.7.5.2 Closure Analysis Considerations

The closure assembly analysis must demonstrate that the lids and bolts satisfy two criteria: (1) calculated maximum stresses must be less than the allowable stress limit (the material yield strength is conservatively selected) and (2) lid deformation and/or rotation at the o-ring locations must be less than the elastic rebound of the o-rings.

Finite element evaluations of the closure are performed using the ANSYS computer program and a two-dimensional axisymmetric model. The critical design load conditions for the NAC-STC closure are three 10 CFR 71 accident loading conditions: (1) impact limiter crush pressure on the outer lid; (2) pin puncture on the outer lid; and (3) impact of the cavity contents on the inner lid. These accident condition analyses are presented in Section 2.7.1.6. The lids and bolts are evaluated at a temperature of 200°F and 270°F, respectively. The impact stresses in the closure components for the normal conditions of transport 1-foot drop are calculated by ratioing the impact stresses calculated in Section 2.7.1.6 according to the g-loads documented in Table 2.6.7.4-3.

The package geometry, package weight, and contents weight are the parameters that control the closure design. This fact is demonstrated to be true by the analysis results in Tables 2.6.7.5-1, -2, -3, and -4, as well as Tables 2.7.1.6-2, -3, -4, and -5. The tables show that the inner lid and bolts (the containment boundary) are critical for end or "near end" impact load conditions and the outer lid bolts are critical for side or "near side" impact load conditions. The closure evaluation presented in this section is for the package (loaded NAC-STC cask with impact limiters as described on the drawings in Section 1.3.2) with a total weight of 260,000 pounds and a cavity contents weight of 67,196 pounds. This evaluation envelopes all of the NAC-STC cask configurations, i.e., the directly loaded fuel configuration, the canistered fuel configuration, and the canistered GTCC waste configuration. The package geometry is identical for all of the configurations. Therefore, the closure analyses in this section and in Sections 2.7.1.6, 2.7.3.4, and 2.10.8 are applicable for the directly loaded and the canistered configurations of the NAC-STC.

2.6.10.1 Impact Limiter - Penetration

There are two NAC-STC cask impact limiter configurations. The first is constructed of redwood and balsa and may be used in the transport of directly loaded fuel or the Yankee-MPC canistered fuel or GTCC waste. This impact limiter configuration is referred to as the redwood impact limiter. The second is constructed of all balsa and must be used with the CY-MPC canistered fuel or GTCC waste configurations, but may be used with the directly loaded and Yankee-MPC configurations. Both impact limiter configurations have the impact absorbing wood enclosed in a stainless steel shell.

2.6.10.1.1 Redwood Impact Limiter Penetration

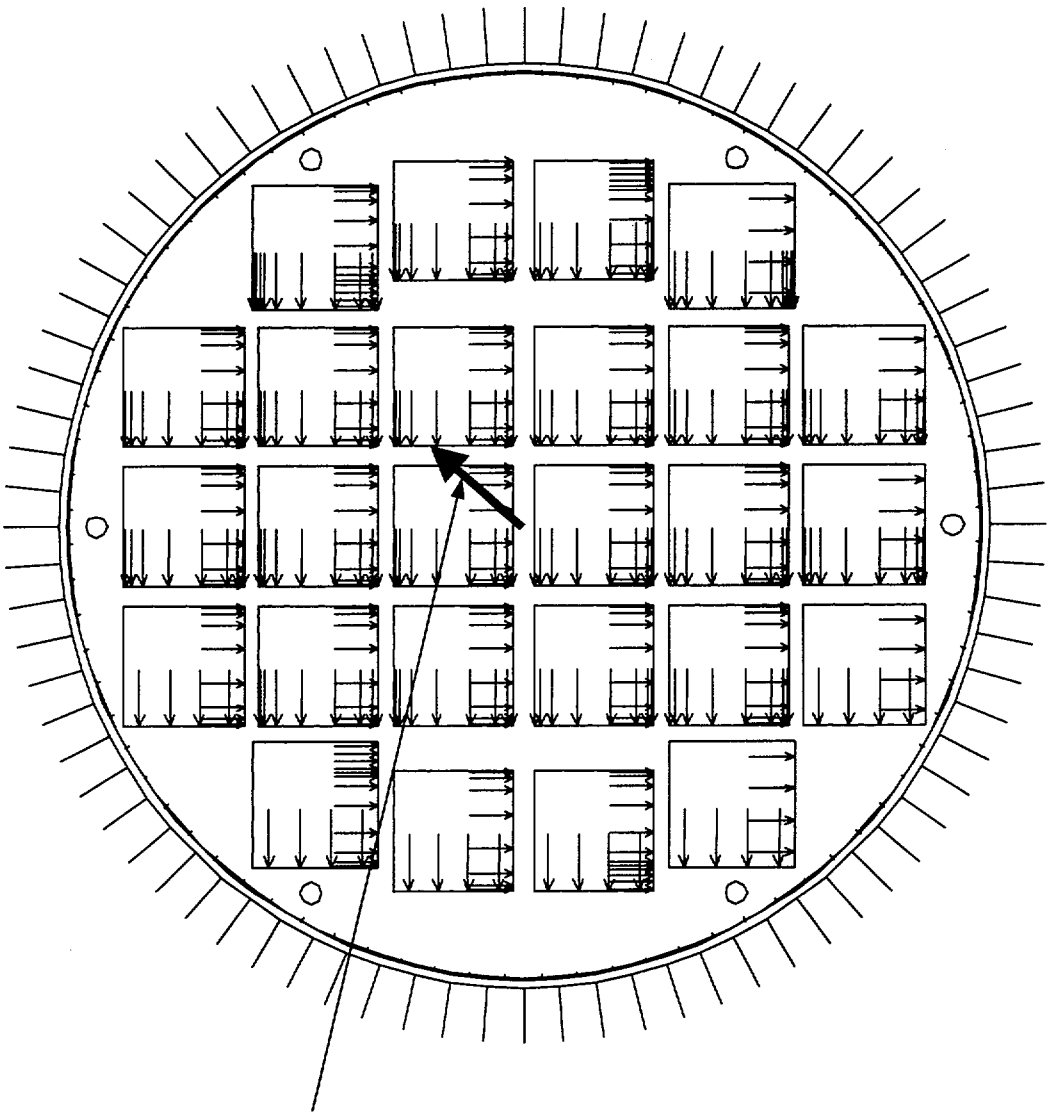
The 0.25-inch thick stainless steel outer shell of the impact limiter, backed by redwood and balsa wood, resists puncture by the penetration cylinder. However, the puncture resistance of the shell is conservatively not considered in this analysis. The 13-pound penetration cylinder drops 40 inches, producing (13)(40) = 520 inch-pounds of energy, which is assumed to be absorbed only by the redwood and balsa wood materials. The minimum crush strength of the redwood material in the perpendicular to the grain direction is about 500 psi for initial strain conditions. The perpendicular to the grain direction corresponds to the penetration cylinder impacting the end of the impact limiter and bounds an impact on the side of the limiter where the redwood is oriented in the stronger parallel to the grain direction. The area of the penetration cylinder is 1.227 square inches. Therefore, using the redwood crush strength and the average impact area in the conservation of energy equation, the penetration cylinder might penetrate bare redwood material to a depth of 520/[(500)(1.227)/2] = 1.7 inches. This depth of penetration would not significantly affect the performance of the impact limiter.

2.6.10.1.2 Balsa Impact Limiter Penetration

Similar to the redwood impact limiter evaluation, the 0.25-inch thick stainless steel outer shell of the balsa impact limiter, backed by balsa wood, resists puncture by the penetration cylinder. The dropped cylinder produces 520 inch-pounds of energy, which is absorbed by the balsa wood. The minimum crush strength of the balsa wood in the parallel to the grain direction, is about 1,500 psi for initial strain conditions. The parallel to grain direction of the balsa wood corresponds to the penetration cylinder impacting the end of the impact limiter and bounds an impact on the side of the limiter where the redwood is oriented in the parallel to the grain

direction. The area of the penetration cylinder is 1.227 square inches. Therefore, using the balsa wood crush strength and the average impact area in the conservation of energy equation, the penetration cylinder might penetrate bare balsa wood material to a depth of 520/[(1,500)(1.227)/2] = 0.57 inches. This depth of penetration would not significantly affect the performance of the impact limiter.

Figure 2.6.16.2-1 CY-MPC Support Disk Side Drop Model



Note: mesh is omitted for clarity.

Figure 2.6.16.2-2 CY-MPC Support Disk End Drop Model

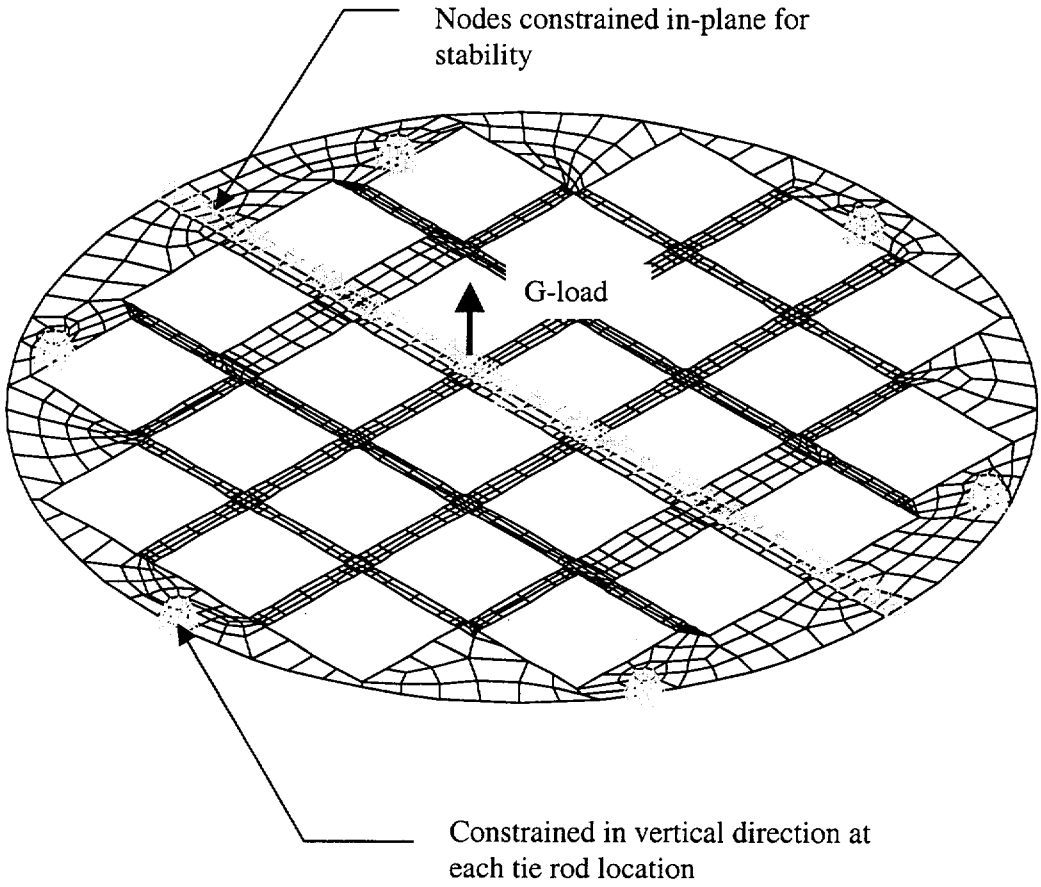


Figure 2.6.16.2-5 Location of the Sections to Obtain Linearized Stresses – CY-MPC Basket Support Disk

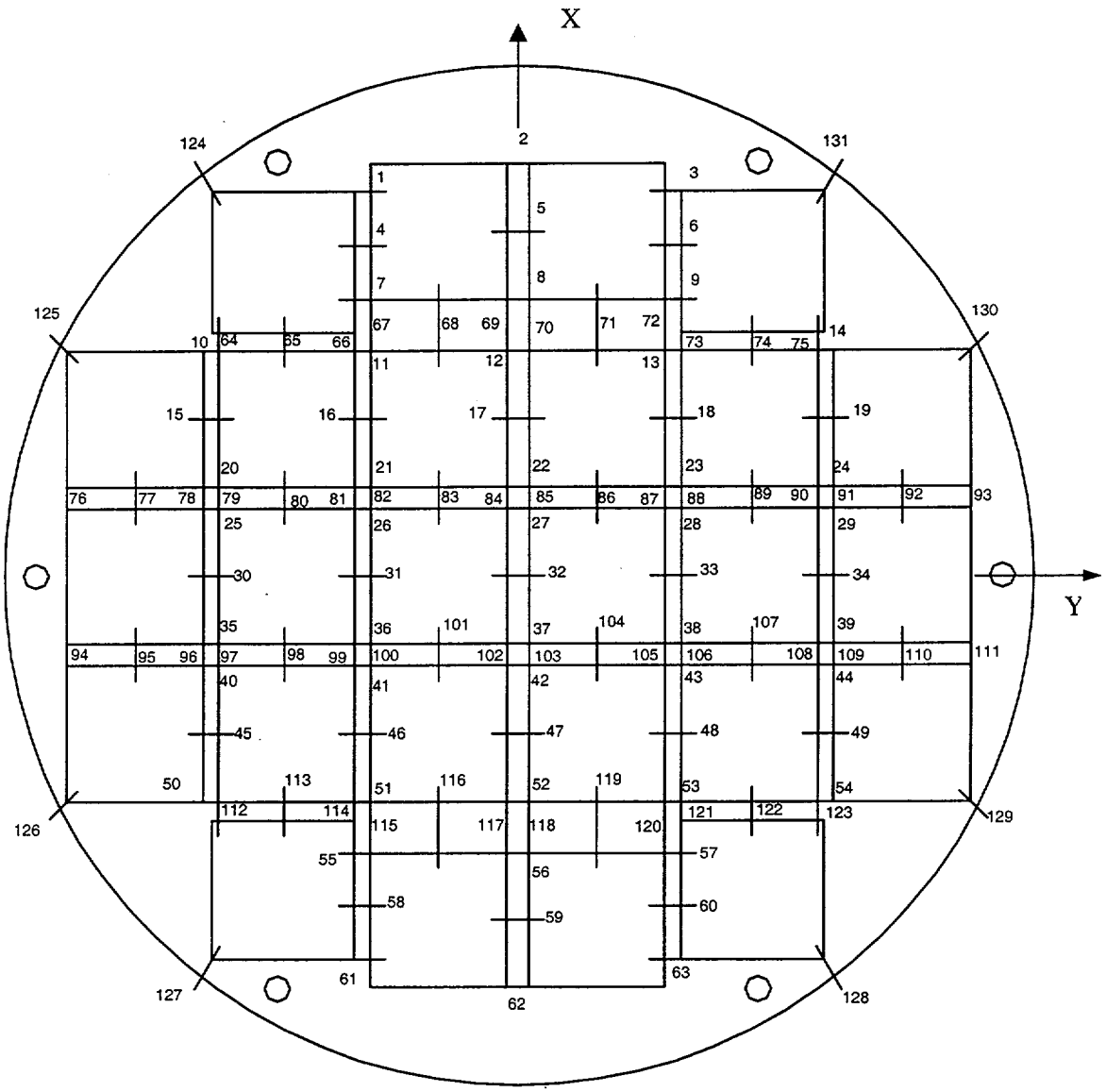


Table 2.6.16.2-1 Cross Sections for Stress Evaluation of CY-MPC Support Disk

SECTION	POINT 1		POINT 2	
	X	Y	X	Y
1	26.075	-9.92	26.075	-11.02
2	27.925	0.75	27.925	-0.75
3	26.075	9.92	26.075	11.02
4	22.415	-9.92	22.415	-11.02
5	23.34	0.75	23.34	-0.75
6	22.415	9.92	22.415	11.02
7	18.755	-9.92	18.755	-11.02
8	18.755	0.75	18.755	-0.75
9	18.755	9.92	18.755	11.02
10	15.255	-20.19	15.255	-21.19
11	15.255	-9.92	15.255	-11.02
12	15.255	0.75	15.255	-0.75
13	15.255	9.92	15.255	11.02
14	15.255	20.19	15.255	21.19
15	10.67	-20.19	10.67	-21.19
16	10.67	-9.92	10.67	-11.02
17	10.67	0.75	10.67	-0.75
18	10.67	9.92	10.67	11.02
19	10.67	20.19	10.67	21.19
20	6.085	-20.19	6.085	-21.19
21	6.085	-9.92	6.085	-11.02
22	6.085	0.75	6.085	-0.75
23	6.085	9.92	6.085	11.02
24	6.085	20.19	6.085	21.19
25	4.585	-20.19	4.585	-21.19
26	4.585	-9.92	4.585	-11.02
27	4.585	0.75	4.585	-0.75
28	4.585	9.92	4.585	11.02
29	4.585	20.19	4.585	21.19
30	0	-20.19	0	-21.19
31	0	-9.92	0	-11.02
32	0	0.75	0	-0.75
33	0	9.92	0	11.02
34	0	20.19	0	21.19
35	-4.585	-20.19	-4.585	-21.19
36	-4.585	-9.92	-4.585	-11.02
37	-4.585	0.75	-4.585	-0.75
38	-4.585	9.92	-4.585	11.02

2.6.16.4 Stress Evaluation of the CY-MPC Support Disk for a 1-Foot End Drop

Six (6) tie rods locate the support disks of the canistered fuel basket with spacers. A structural analysis is performed using ANSYS to evaluate the effect of a 1-foot end drop impact, which corresponds to the most severe out-of-plane loading under normal conditions. The model described in Section 2.6.16.2 is used with a 20g deceleration. Linearized stresses at the cross sections identified in Figure 2.6.16.2-5 are compared to stress allowables in accordance with the ASME Code, Section III, Subsection NG.

The allowable stress intensity for P_m is S_m. For 17-4PH material, this value is equal to 42.5 ksi at 650°F and 45.0 ksi at –40°F. The allowable stress intensity for $P_m + P_b$ is 1.5 S_m. For 17-4PH material, this value is equal to 63.8 ksi at 650°F and 67.5 ksi at –40°F.

The minimum margin of safety is 0.76 $P_m + P_b$ stresses. Table 2.6.16.4-1 list the 10 highest $P_m + P_b$ stress intensities, respectively. Locations of the 10 highest $P_m + P_b$ stress intensities are shown in Figure 2.6.16.4-1. During an end drop, there are no membrane stresses in the support disk because there is no inplane loading with the exception of thermal stresses, which are reported in the P+Q results.

Figure 2.6.16.4-1 Locations of CY-MPC Support Disk Maximum $P_m + P_b$ Stresses, 1-Foot End Drop

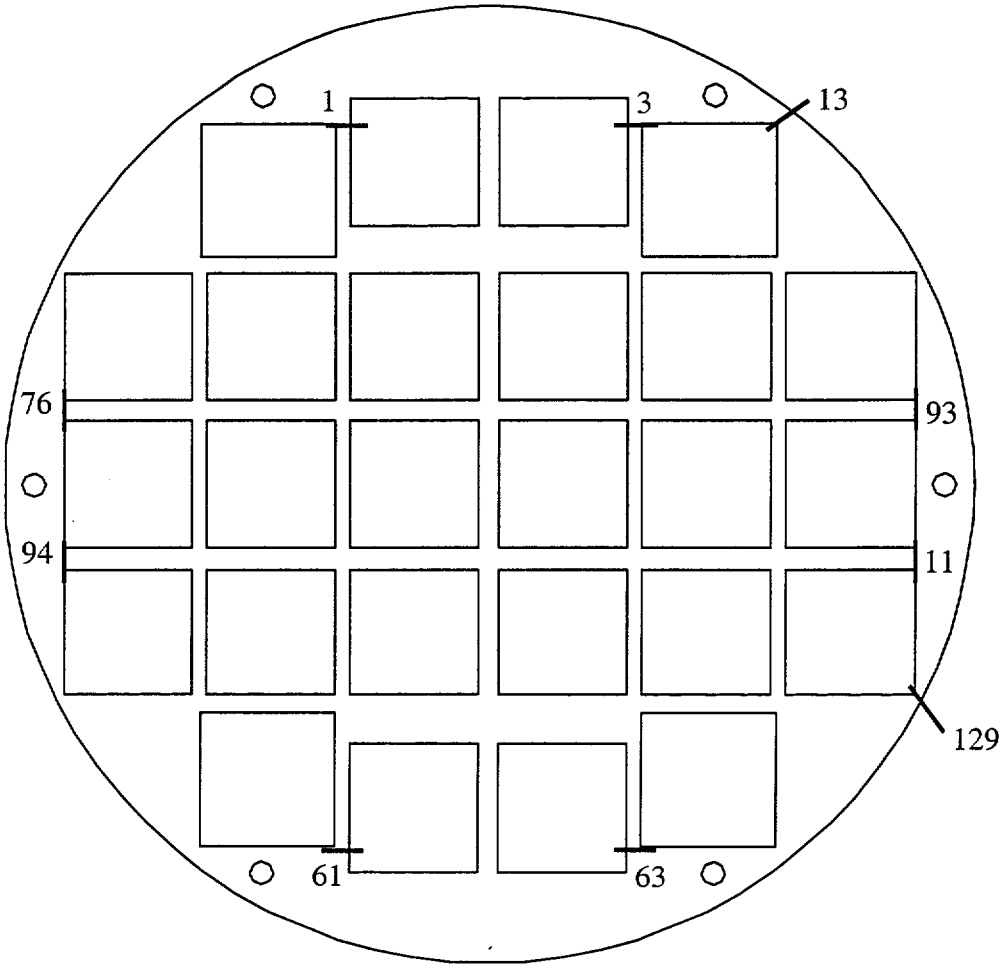


Table 2.6.16.4-1 $P_m + P_b$ Stresses for CY-MPC Support Disk, 1-Foot End Drop

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
61	31.40	-6.10	11.90	36.20	63.80	0.76
63	31.70	-6.40	-11.10	35.80	63.80	0.78
3	31.50	-6.00	11.80	36.10	65.50	0.82
1	31.60	-5.90	-11.10	35.80	65.50	0.83
76	-1.40	-18.70	5.80	23.10	63.90	1.76
93	-1.50	-18.70	-5.50	23.10	63.90	1.77
94	-1.50	-18.50	-5.60	22.90	63.80	1.79
111	-0.30	-19.60	5.00	22.40	63.80	1.85
129	-16.80	4.20	-5.40	18.80	63.80	2.39
125	-16.80	4.20	-5.40	18.80	64.40	2.43

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

2.6.16.5 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot End Drop Load Condition

The thermal expansion loads described in Section 2.6.16.3 are applied to the finite element model simultaneously with the 20g end drop loads described in Section 2.6.16.4 to produce a combined thermal expansion plus end impact loading. The stress evaluation results for thermal plus the 1-foot end drop conditions are summarized below. The allowable stress is 3.0 S_m in accordance with the ASME Code, Section III, Subsection NG for primary plus secondary (P+Q) stress intensity range. The minimum margin of safety is +2.63. The thermal condition used bounds both the maximum support disk temperature (Tmax = 550°F) and the maximum thermal gradient across the disk (ΔT = 225°F). Table 2.6.16.5-1 shows the 10 highest $P_m + P_b + Q$ stress intensities for a 1 ft end drop. Figure 2.6.16.5-1 shows the locations of the 10 highest stress intensities for this case.

$P_m + P_b + Q$	
Stress Intensity (ksi)	Margin of Safety
35.1	2.63

Figure 2.6.16.5-1 Locations of Maximum $P_m + P_b + Q$ Stresses for CY-MPC Support Disk for a 1-Foot End Drop, T_{max} = 550°F and T_{min} = 325°F

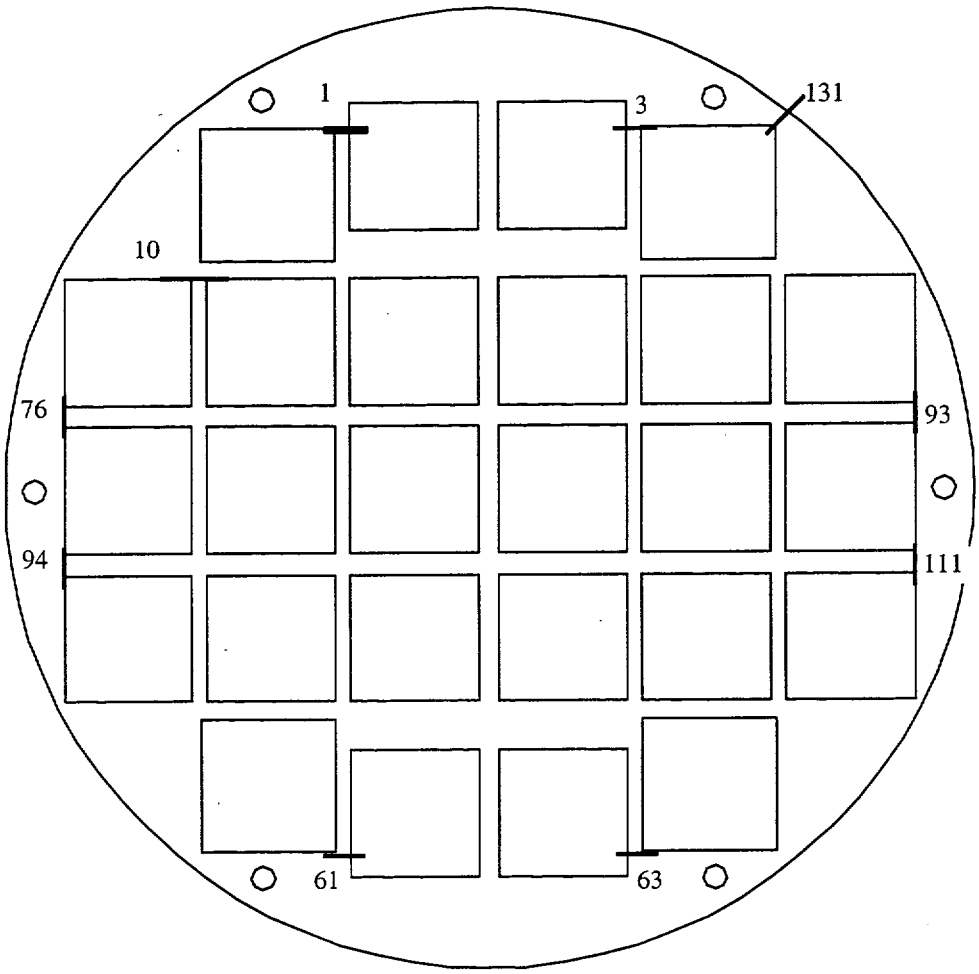


Table 2.6.16.5-1 P + Q Stresses for CY-MPC Support Disk—1-Foot End Drop
T_{max} = 550°F and T_{min} = 325°F

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
61	30.40	-5.80	11.80	35.10	127.50	2.63
63	30.60	-6.10	-11.00	34.80	127.50	2.67
3	29.10	-5.10	11.50	33.70	131.10	2.89
1	29.20	-4.90	-10.80	33.30	131.10	2.93
93	-2.50	-19.30	-5.10	24.00	127.70	4.31
76	-2.30	-19.30	5.30	24.00	127.70	4.33
94	-2.40	-18.30	-5.20	23.20	127.50	4.49
111	-1.30	-19.40	4.70	22.60	127.50	4.63
131	6.10	7.20	-6.30	18.40	130.10	6.08
10	-3.80	-9.50	-6.10	18.10	129.10	6.14

Note: See Figure 2.6.16.2-5 for section locations and definition of the coordinate system.

2.6.16.6 Stress Evaluation of CY-MPC Tie Rods and Spacers for 1-Foot End Drop

Tie Rods

The tie rods serve basket assembly purposes and are not part of the load path for the conditions evaluated. The tie rods are pre-loaded in tension during basket assembly by an initial applied torque (T) of 50 ± 10 ft-lb. The resulting initial tension (P_b) in each tie rod is:

$$P_b = \frac{T}{0.159L + 1.156\mu d} = \frac{60(12)}{0.159(0.125) + 1.156(0.18)(1.625)} = 2{,}011 \text{ lbs.} \quad \text{(Machinery's)}$$

where:

T = 60 ft-lb (maximum wrench torque)
μ = 0.18, (for lubricated threads)
d = 1.625 in. (tie rod nominal diameter)
L = 1/n = 1/8 (n = number of threads)

The tie rods are not loaded during drop conditions; therefore, no structural analysis is required.

Spacers

Six tie rods and cylindrical spacers, to maintain disk spacing, connect the basket support disks and heat transfer disks. In a side drop, the load path is through the support disks into the canister wall. In an end drop, the load path is through the spacers to either the canister lid or bottom depending on the drop orientation. The load comprises the weight of the top or bottom weldment (depending on the drop orientation), the weight of the support and heat transfer disks, and the weight of the spacers and washers. The weight of the fuel assemblies is transmitted directly into the canister lid or bottom because the fuel tubes in the basket are open at both ends. In drop orientations between a side drop and an end drop, only a portion of the load acts along the tie rod axis. Thus, the end drop is the critical loading condition for the spacers. The bottom-end drop is the governing case because the top weldment is heavier than the bottom weldment.

During an end drop, the 6 split spacers at the bottom of the heat transfer disk array are loaded by the top weldment, the 27 heat transfer disks, the spacers and washers above, and the 28 support disks. The total weight on the split spacers is 8,225 pounds.

The initial tie rod pre-load, tension, will be diminished by the compressive effect of the end drop. However, for conservatism, the total compression (2,011 lbs) induced by the 50±10 ft-lb bolt torque will be included in the load on the split spacers.

The maximum total load (P_{ssp}) on the split spacer is, for normal conditions:

$$P_{ssp} = 2{,}011 + (8{,}225)\times 20g/6 = 33{,}847 \text{ lb, use } 29{,}428 \text{ lb}$$

The stress (σ_{ssp}) is determined by applying the total load to the cross-sectional area (A_{ssp}) of the split spacer. A_{ssp} is conservatively taken as the area of the decreased diameter section.

$$\sigma_{ssp} = \frac{P_{ssp}}{A_{ssp}} = \frac{35{,}000 \text{ lb}}{2.45 \text{ in.}^2} = 14{,}286 \text{ psi}$$

Where

$$A_{ssp} = \frac{\pi}{4}\left(2.50^2 - 1.77^2\right) = 2.45 \text{ in}^2$$

The margin of safety (MS) is:

$$MS = \frac{1.0S_m}{\sigma_{ssp}} - 1 = \frac{18{,}700}{14{,}286} - 1 = +0.31 \quad \text{(Normal condition, 400°F)}$$

The load on the bottom spacers comprises the weight of the top weldment, the weight of the support and heat transfer disks, and the weight of the spacers and washers.

During a bottom end drop, the 6 bottom spacers support the top weldment, the 27 heat transfer disks, the spacers and washers above, and the 28 support disks. The total weight on the spacers is 9,874 lbs.

The initial tie-rod pre-load tension will be diminished by the compressive effect of the end drop. However, for conservatism, the total compression (2,011 lbs) induced by the 50±10 ft-lb bolt torque will be included in the load on the bottom spacers.

The maximum total load (P_{bsp}) on the bottom spacer is:

$$P_{bsp} = 2{,}011 + (9{,}874)\times 20/6 = 34{,}924\text{lbs. (use 35,000 lbs)}$$

The stress (σ_{bsp}) is determined by applying the total load to the cross-sectional area (A_{bsp}) of the bottom spacer.

$$\sigma_{bsp} = \frac{P_{bsp}}{A_{bsp}} = \frac{35{,}000 \text{ lbs}}{4.03 \text{ in.}^2} = 8{,}685 \text{ psi}$$

Where

$$A_{bsp} = \frac{\pi}{4}\left(2.875^2 - 1.77^2\right) = 4.03 \text{ in}^2$$

The margin of safety (MS) is:

$$MS = \frac{1.0S_m}{\sigma_{bsp}} - 1 = \frac{17{,}400}{8{,}685} - 1 = +1.00 \quad \text{(Normal condition, 400°F)}$$

2.6.16.7 Stress Evaluation of CY-MPC Support Disk for a 1-Foot Side Drop

To determine the structural adequacy of the support disk in the 1-foot side drop impact load condition, a quasi-static impact load equal to the weight of the fuel and tubes multiplied by a 20g amplification factor is applied to the support disk structure. The inertial loading of the support disk is included via the density input for the 17-4 PH stainless steel. The value of 20g is conservative since the impact limiter design deceleration for a 1-foot side drop is 16.5g. The fuel assembly load is transmitted by direct compression through the tube wall to the web structure of the support disk. The maximum in-plane loading occurs in the side drop, which is evaluated using a finite element analysis. The analysis is performed using the three-dimensional support disk side drop model described in Section 2.6.16.2. As discussed in Section 2.6.16.1, four bounding cases of basket orientation (0°, 38°, 63°, and 90°) are considered in the analysis.

As described in Section 2.6.16.5, the material properties are evaluated at a bounding thermal condition which bounds both the maximum disk temperature combined with the maximum thermal gradient across the disk. Specifically, the maximum disk temperature is equal to 550°F and the minimum disk temperature is equal to 325°F. Linearized stresses at the cross-sections (Figures 2.6.16.2-5) are compared to the stress allowable per the ASME Code, Section III, Subsection NG.

Primary membrane (P_m) stress intensity is compared to 1.0 S_m and primary membrane plus bending (P_m+P_b) stress intensity is compared to 1.5 S_m for the material at the temperature corresponding to each section location. The stress evaluation results for the 1-foot side-drop condition are summarized in Table 2.6.16.7-1. The minimum margin of safety is +0.15, which occurs for a 38° basket orientation. Tables 2.6.16.7-2 through 2.6.16.7-9 list the 30 highest P_m and P_m+P_b stress intensities at each basket orientation considered. Locations of the 10 highest P_m and P_m+P_b stresses are shown in Figures 2.6.16.7-1 and 2.6.16.7-2 at the worst case drop angle of 38°.

Figure 2.6.16.7-1 Locations of CY-MPC Support Disk Maximum P_m Stresses, 1-Foot Side Drop, 38° Orientation

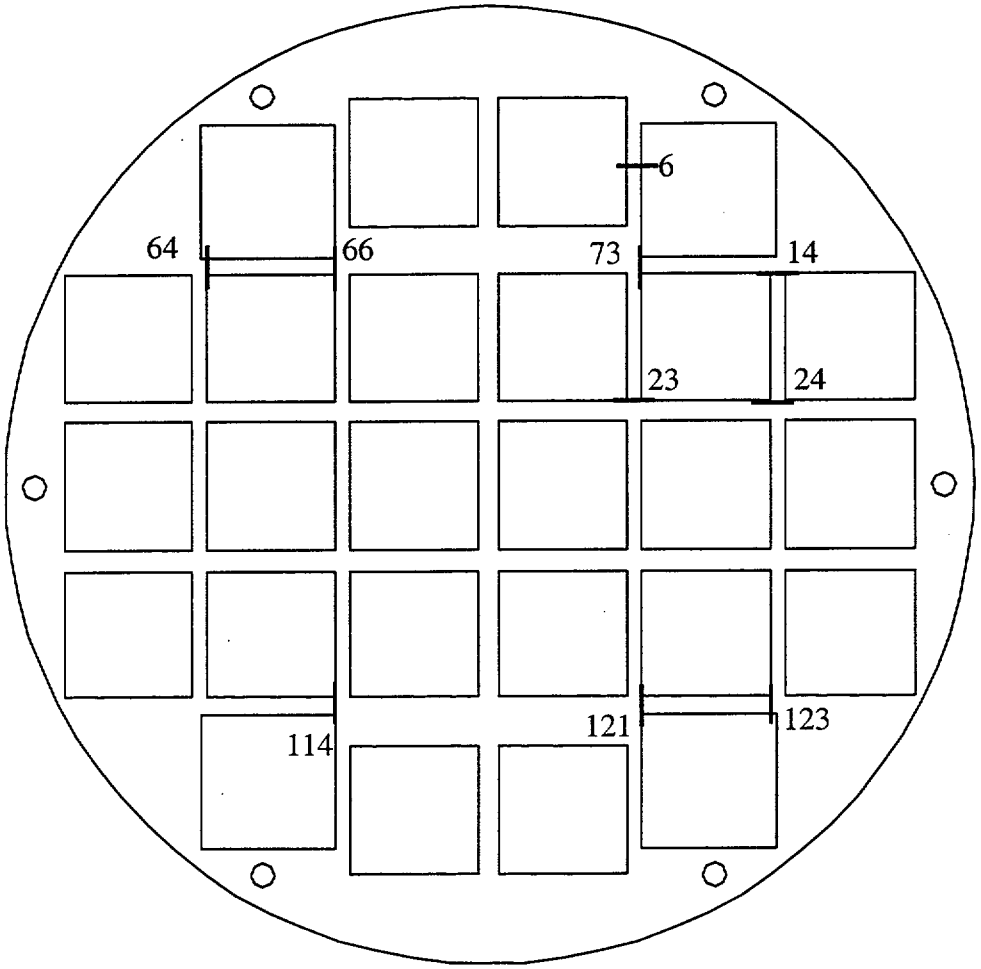


Figure 2.6.16.7-2 Locations of CY-MPC Support Disk Maximum $P_m + P_b$ Stresses, 1-Foot Side Drop, 38° Orientation

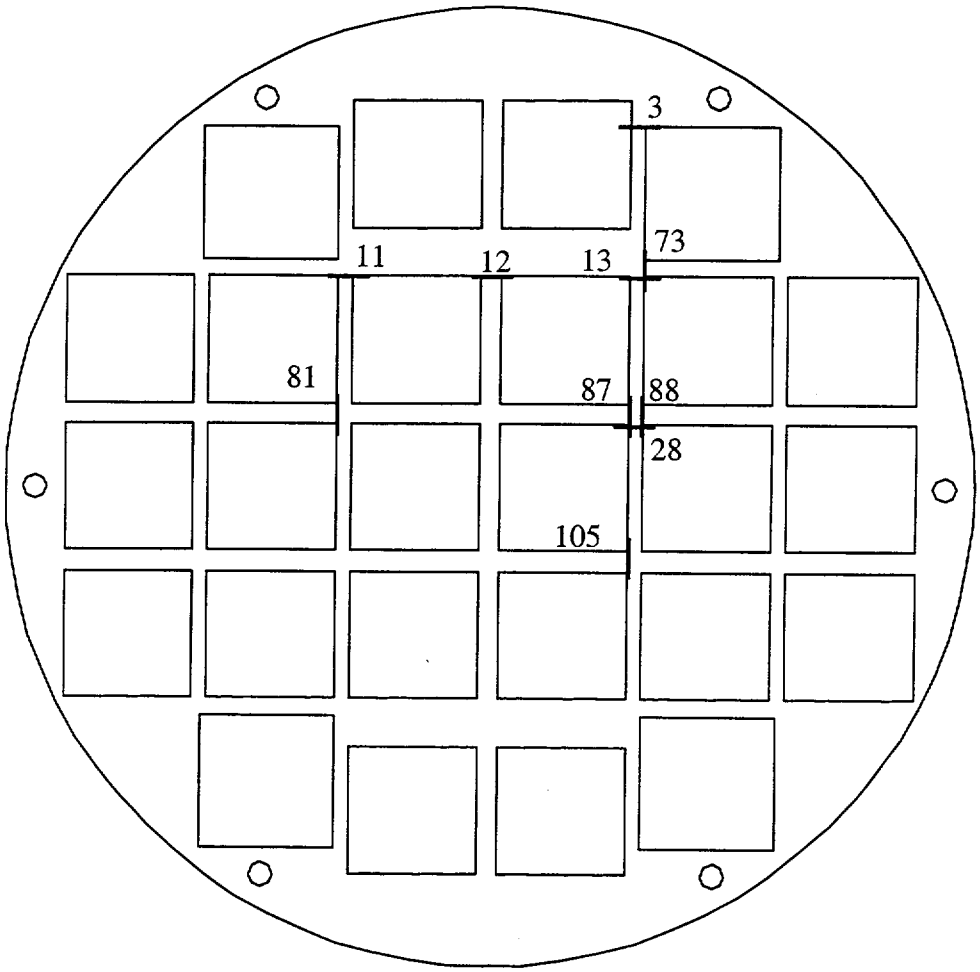


Table 2.6.16.7-1 Summary of Maximum CY-MPC Support Disk Stresses for 1-Foot Side Drop

P_m		P_m+P_b	
Section	**Margin of Safety**	**Section**	**Margin of Safety**
0° Basket Orientation			
2	1.34	1	1.09
11	1.41	3	1.14
13	1.44	9	1.42
12	1.51	7	1.43
1	1.57	11	2.01
38° Basket Orientation			
73	0.35	13	0.15
66	0.96	3	0.18
6	1.39	28	0.23
14	1.45	88	0.29
114	1.58	87	0.30
63° Basket Orientation			
73	0.81	28	0.34
66	1.13	43	0.36
121	1.34	106	0.38
24	1.36	105	0.38
114	1.45	88	0.38
90° Basket Orientation			
108	0.87	129	0.99
90	0.87	108	1.40
105	1.56	90	1.44
87	1.56	44	1.54
44	2.03	24	1.58

Table 2.6.16.7-2 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 0° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
2	-12.70	-6.20	0.00	18.80	44.00	1.34
11	-8.40	-9.30	1.10	17.90	43.10	1.41
13	-8.40	-9.20	-1.10	17.70	43.10	1.44
12	-10.00	-7.30	0.00	17.20	43.20	1.51
1	-12.80	-4.20	0.30	17.00	43.70	1.57
3	-12.70	-4.00	-0.30	16.70	43.70	1.61
5	-16.60	0.00	0.00	16.60	43.60	1.63
9	-12.90	-3.20	-0.30	16.10	43.20	1.69
7	-12.60	-2.80	-0.10	15.40	43.20	1.81
27	-8.70	-5.50	0.00	14.20	42.70	1.99
8	-12.90	10.00	0.00	12.90	43.30	2.36
131	-11.60	5.50	2.40	12.40	43.40	2.50
26	-6.20	-5.80	0.70	12.10	42.60	2.52
28	-6.20	-5.80	-0.70	12.00	42.60	2.55
17	-11.70	0.00	0.00	11.70	42.90	2.67
69	-9.40	-1.70	-0.80	11.20	43.20	2.85
4	-11.00	0.00	-1.10	11.20	43.50	2.87
6	-10.90	0.00	1.10	11.20	43.50	2.89
70	-9.30	-1.70	0.80	11.10	43.20	2.89
42	-6.90	-3.90	0.00	10.80	42.50	2.93
22	-10.00	5.50	0.00	10.00	42.70	3.27
16	-9.80	0.00	-0.60	9.80	42.90	3.36
18	-9.70	0.00	0.50	9.80	42.90	3.38
32	-9.60	0.00	0.00	9.60	42.50	3.42
73	-6.20	-3.40	0.30	9.50	43.10	3.52
66	-6.20	-3.30	-0.30	9.50	43.10	3.52
85	-7.80	-1.30	0.50	9.20	42.70	3.62
84	-7.80	-1.30	-0.50	9.20	42.70	3.63
21	-8.10	6.00	0.60	8.20	42.70	4.19
41	-3.60	-4.50	0.50	8.20	42.50	4.19

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.7-3 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
73	-31.70	2.10	2.50	31.90	43.10	0.35
66	21.50	0.30	1.50	22.00	43.10	0.96
6	-17.30	0.20	-3.20	18.20	43.50	1.39
14	-8.40	-8.80	1.80	17.60	43.00	1.45
114	-14.60	-1.80	1.10	16.50	42.50	1.58
24	-8.40	14.60	2.70	15.60	42.60	1.73
121	14.90	-0.20	2.10	15.20	42.50	1.79
123	-10.50	-3.30	0.90	13.90	42.50	2.07
23	-9.00	9.50	4.30	13.50	42.70	2.15
64	-10.00	-3.00	2.10	13.60	43.00	2.16
91	-11.40	4.40	4.30	13.40	42.60	2.17
13	-11.80	-0.80	1.60	13.10	43.10	2.30
39	-6.20	11.50	2.50	12.50	42.50	2.39
29	-6.90	-5.10	1.70	12.50	42.60	2.40
88	-9.90	3.30	4.60	12.30	42.60	2.48
1	-3.50	-9.00	-0.30	12.50	43.70	2.49
18	-11.00	0.10	-2.70	12.20	42.90	2.51
85	-2.50	2.40	6.10	12.10	42.70	2.52
103	-4.20	1.10	5.80	11.90	42.50	2.56
28	-7.10	-2.40	3.60	11.90	42.60	2.57
55	5.00	6.80	0.70	11.90	42.50	2.57
38	-6.40	7.70	4.20	11.30	42.50	2.77
75	5.00	6.20	0.30	11.30	43.00	2.82
19	-10.60	0.10	-1.70	11.10	42.80	2.87
44	-4.90	-5.40	1.80	10.90	42.50	2.89
7	-3.30	-7.60	0.60	11.00	43.20	2.94
54	-2.90	10.20	1.90	10.70	42.50	2.97
84	-4.00	2.40	5.30	10.70	42.70	2.99
10	3.70	7.00	0.30	10.70	43.00	3.02
43	-4.50	-3.30	3.40	10.40	42.50	3.07

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.7-4 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 63° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
73	-23.50	6.40	2.00	23.80	43.10	0.81
66	18.20	1.90	1.20	20.20	43.10	1.13
121	17.90	-1.00	1.90	18.10	42.50	1.34
24	-5.00	17.40	2.80	18.10	42.60	1.36
114	-14.80	-2.40	1.20	17.40	42.50	1.45
75	5.90	11.10	0.60	17.10	43.00	1.52
123	-11.90	-4.20	1.40	16.30	42.50	1.61
91	-11.80	9.10	4.00	14.70	42.60	1.91
90	3.70	8.00	3.20	13.30	42.60	2.20
39	-3.30	12.30	3.10	13.20	42.50	2.21
102	5.30	2.30	5.00	12.50	42.50	2.40
88	-8.80	7.40	3.90	12.10	42.60	2.52
81	5.90	3.90	3.20	11.60	42.60	2.67
64	-10.60	-0.30	2.00	11.60	43.00	2.72
84	2.00	5.10	4.50	11.50	42.70	2.72
109	-6.70	7.00	4.40	11.30	42.50	2.78
87	2.90	6.40	3.10	11.20	42.70	2.81
103	-5.40	3.90	5.40	10.80	42.50	2.93
108	1.00	6.10	4.00	10.70	42.50	2.96
92	-0.10	10.60	-1.20	10.70	42.60	2.97
78	6.70	2.20	3.00	10.70	42.60	2.98
23	-3.60	8.10	4.10	10.50	42.70	3.06
38	-2.20	7.20	4.40	10.20	42.50	3.17
14	-4.80	-4.70	1.80	10.20	43.00	3.23
112	9.50	-1.10	2.20	10.00	42.50	3.24
85	-3.50	5.80	4.90	10.10	42.70	3.24
106	-5.70	5.60	4.30	10.00	42.50	3.26
105	2.40	4.60	3.40	9.80	42.50	3.36
89	-0.10	8.60	-1.80	9.20	42.70	3.61
6	-8.10	0.20	-2.50	9.40	43.50	3.64

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.7-5 P_m Stresses for CY-MPC Support Disk 1-Foot Side Drop, 90° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
108	12.00	10.70	0.80	22.70	42.50	0.87
90	12.00	10.70	-0.70	22.70	42.60	0.87
105	8.10	8.50	0.40	16.60	42.50	1.56
87	8.10	8.50	-0.40	16.60	42.70	1.56
44	4.50	9.50	-0.40	14.00	42.50	2.03
24	4.60	9.40	0.40	14.00	42.60	2.05
110	0.00	13.40	-0.40	13.40	42.50	2.16
92	0.00	13.40	0.40	13.50	42.60	2.17
102	7.40	5.90	0.70	13.40	42.50	2.17
84	7.40	5.90	-0.60	13.40	42.70	2.18
29	4.70	8.30	-1.20	13.20	42.60	2.22
39	4.70	8.10	1.20	13.10	42.50	2.24
109	-5.30	11.90	0.70	11.90	42.50	2.56
91	-5.20	11.90	-0.60	11.90	42.60	2.57
107	0.00	11.20	-0.20	11.20	42.50	2.80
89	0.00	11.20	0.20	11.20	42.70	2.80
129	-6.20	9.10	-3.10	11.00	42.50	2.85
81	6.80	4.10	-0.40	10.90	42.60	2.91
99	6.70	4.10	0.50	10.90	42.50	2.91
111	-1.30	10.80	-0.10	10.80	42.50	2.92
93	-0.90	10.80	0.30	10.80	42.60	2.94
106	-7.60	9.80	0.50	9.90	42.50	3.30
88	-7.60	9.80	-0.50	9.90	42.60	3.31
130	-3.70	8.90	1.20	9.20	42.90	3.67
104	0.00	8.90	-0.30	9.00	42.50	3.75
38	1.00	7.70	1.10	8.90	42.50	3.75
86	0.00	9.00	0.30	9.00	42.70	3.75
28	1.00	7.70	-1.10	8.90	42.60	3.78
14	4.40	4.20	-0.60	8.70	43.00	3.95
54	4.20	4.20	0.30	8.40	42.50	4.07

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.7-6 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 0° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	-31.30	1.10	0.90	31.40	65.50	1.09
3	-30.70	1.00	-0.90	30.70	65.50	1.14
9	-26.80	0.10	-0.80	26.80	64.90	1.42
7	-26.70	1.50	0.80	26.70	64.90	1.43
11	-16.30	-4.90	1.60	21.50	64.70	2.01
13	-16.20	-4.90	-1.60	21.30	64.70	2.04
2	-12.60	-6.40	0.80	19.10	66.00	2.46
70	-6.30	-10.80	-1.60	17.40	64.80	2.73
69	-6.20	-10.80	1.70	17.40	64.80	2.73
12	-10.00	-7.30	0.70	17.30	64.80	2.75
81	-16.30	9.80	-1.40	16.60	64.00	2.85
131	-14.90	8.60	4.00	16.80	65.10	2.87
88	-16.20	9.70	1.40	16.40	64.00	2.89
66	-16.10	8.20	-2.00	16.60	64.70	2.90
21	-15.80	11.20	-1.70	16.40	64.00	2.90
23	-15.70	11.00	1.70	16.30	64.00	2.94
5	-16.60	0.00	0.00	16.60	65.40	2.94
73	-16.00	7.90	1.90	16.40	64.70	2.95
64	1.70	-16.20	-0.20	16.20	64.50	2.98
67	-12.80	-3.00	0.90	15.90	64.70	3.08
72	-12.60	-3.10	-0.80	15.80	64.70	3.09
8	-13.00	10.00	-3.60	15.50	64.90	3.20
75	1.70	-14.90	0.20	14.90	64.50	3.33
124	-8.20	10.30	-5.50	14.80	65.20	3.40
27	-8.80	-5.50	-0.10	14.30	64.00	3.49
82	-9.40	-4.40	0.30	13.90	64.00	3.62
87	-9.30	-4.40	-0.30	13.70	64.00	3.67
26	-12.00	-1.30	1.00	13.40	64.00	3.76
28	-11.80	-1.30	-0.90	13.30	64.00	3.82
85	-5.40	-7.50	-0.70	12.90	64.00	3.95

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.7-7 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
13	-56.30	19.50	1.90	56.40	64.70	0.15
3	-54.50	19.80	-6.30	55.60	65.50	0.18
28	-51.70	28.50	3.20	52.10	64.00	0.23
88	-49.50	19.30	2.10	49.60	64.00	0.29
87	-48.90	32.90	2.10	49.20	64.00	0.30
12	-49.20	18.80	-0.20	49.20	64.80	0.31
73	-48.60	9.40	-3.70	49.00	64.70	0.32
105	-47.40	30.40	2.30	47.70	63.70	0.34
11	48.00	-23.10	2.90	48.30	64.70	0.34
81	45.40	-19.90	3.30	45.80	64.00	0.40
82	-45.10	27.50	3.30	45.70	64.00	0.40
26	44.50	-28.00	3.90	45.40	64.00	0.41
2	-46.60	14.10	-1.50	46.70	66.00	0.41
23	-45.00	36.90	1.20	45.20	64.00	0.42
43	-44.30	25.70	3.60	45.00	63.70	0.42
38	-44.30	35.00	1.80	44.60	63.70	0.43
1	-45.10	2.00	4.00	45.50	65.50	0.44
29	-44.00	14.10	1.40	44.10	63.90	0.45
106	-43.60	17.90	2.90	44.00	63.70	0.45
70	-44.30	9.50	1.30	44.40	64.80	0.46
66	44.10	-14.00	-1.70	44.20	64.70	0.46
84	-40.50	36.80	4.40	43.40	64.00	0.47
99	42.50	-21.80	2.90	42.90	63.70	0.48
9	-42.70	18.10	-1.90	42.80	64.90	0.52
22	-39.30	41.40	1.60	42.20	64.00	0.52
41	41.00	-28.60	3.10	41.70	63.70	0.53
100	-40.80	23.30	3.70	41.50	63.70	0.54
72	-41.90	11.20	-0.20	41.90	64.70	0.54
85	-36.40	32.30	5.30	40.00	64.00	0.60
36	38.10	-28.60	3.90	39.50	63.70	0.61

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.7-8 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 63° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
28	-47.30	33.70	2.30	47.60	64.00	0.34
43	-46.20	33.00	3.20	46.90	63.70	0.36
106	-46.00	25.30	2.50	46.30	63.70	0.38
105	45.80	-21.60	3.20	46.20	63.70	0.38
88	-46.10	26.10	1.30	46.20	64.00	0.38
13	-45.50	24.70	1.00	45.50	64.70	0.42
29	-44.10	18.50	1.10	44.10	63.90	0.45
44	-43.00	21.40	1.60	43.20	63.70	0.48
87	42.60	-17.00	3.10	43.00	64.00	0.49
41	41.20	-24.90	3.20	41.80	63.70	0.52
26	41.10	-21.60	3.20	41.60	64.00	0.54
100	-40.90	24.80	2.40	41.20	63.70	0.55
99	41.00	-16.90	2.40	41.20	63.70	0.55
73	-41.30	17.70	-2.90	41.70	64.70	0.55
3	-40.60	18.20	-4.70	41.60	65.50	0.58
109	-40.10	15.10	2.50	40.40	63.70	0.58
111	-13.00	40.00	-2.50	40.30	63.70	0.58
81	39.90	-12.80	2.20	40.00	64.00	0.60
82	-39.60	25.80	1.70	39.80	64.00	0.61
42	-37.30	38.30	1.50	39.40	63.70	0.62
53	38.90	-17.90	3.20	39.30	63.70	0.62
52	39.20	-15.40	0.40	39.20	63.70	0.63
103	-36.90	32.70	3.70	39.10	63.70	0.63
102	37.70	-27.20	4.00	39.10	63.70	0.63
91	-38.50	11.30	1.30	38.60	63.90	0.66
108	37.50	-15.90	4.20	38.30	63.70	0.66
38	-36.50	33.60	2.80	38.20	63.70	0.67
11	38.40	-15.80	2.30	38.70	64.70	0.67
75	-5.90	36.80	-0.20	36.80	64.50	0.75
25	36.10	-12.50	1.40	36.20	63.90	0.77

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.7-9 $P_m + P_b$ Stresses for CY-MPC Support Disk 1-Foot Side Drop, 90° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
129	-18.20	21.30	-12.30	32.10	63.70	0.99
108	17.70	8.80	-0.60	26.50	63.70	1.40
90	17.30	8.90	0.60	26.20	63.90	1.44
44	22.90	2.10	-0.10	25.10	63.70	1.54
24	22.50	2.30	0.10	24.80	64.00	1.58
29	11.60	7.40	-1.10	19.10	63.90	2.34
39	11.20	7.50	1.10	18.90	63.70	2.38
105	13.50	5.10	-0.50	18.70	63.70	2.41
130	-12.40	13.50	5.80	18.80	64.30	2.42
87	13.20	5.30	0.50	18.60	64.00	2.44
43	17.00	-1.00	0.70	17.00	63.70	2.74
23	16.80	-0.70	-0.70	16.80	64.00	2.81
111	-3.80	15.80	-2.30	16.30	63.70	2.92
93	-3.00	15.50	2.70	16.10	63.90	2.98
109	-11.50	15.20	-0.90	15.40	63.70	3.14
110	0.00	15.40	-0.40	15.40	63.70	3.14
40	-15.20	7.70	-0.90	15.30	63.70	3.16
92	0.00	15.30	0.40	15.30	63.90	3.19
91	-11.00	14.90	0.90	15.10	63.90	3.22
20	-15.00	7.60	0.90	15.10	64.00	3.25
42	-13.00	13.90	-1.40	14.90	63.70	3.29
22	-12.80	13.60	1.40	14.70	64.00	3.37
14	10.80	3.80	-0.60	14.80	64.60	3.38
54	11.00	3.50	0.30	14.50	63.70	3.40
106	-12.70	12.20	-2.00	14.40	63.70	3.42
88	-12.40	12.10	2.00	14.30	64.00	3.49
41	-13.90	11.30	-0.90	14.20	63.70	3.49
28	7.20	6.90	-0.10	14.10	64.00	3.53
38	6.90	7.10	0.10	14.00	63.70	3.55
21	-13.70	11.10	1.00	14.00	64.00	3.58

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

2.6.16.8 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot Side Drop Load Condition

The loading for the 1-foot side drop (Section 2.6.16.7) is combined with the thermal loading (Section 2.6.16.3) to produce a combined thermal plus impact loading condition. The allowable P + Q stress intensity range is $3S_m$.

The stress evaluation results for thermal plus 1-foot side drop condition are summarized in Table 2.6.16.8-1. The thermal condition is identical to that used in Section 2.6.16.7, except that the thermal expansion stresses are included in this calculation. The minimum margin of safety is +1.95, which occurs at the 38° basket drop orientation. Tables 2.6.16.8-2 through 2.6.16.8-5 list the 30 highest P+Q stress intensities for each basket orientation considered. Locations of the 10 highest P+Q stress intensities at the worst-case 38° basket orientation are shown in Figure 2.6.16.8-1.

Figure 2.6.16.8-1 Locations of CY-MPC Support Disk Maximum P + Q Stresses, 1-Foot Side Drop, 38° Orientation

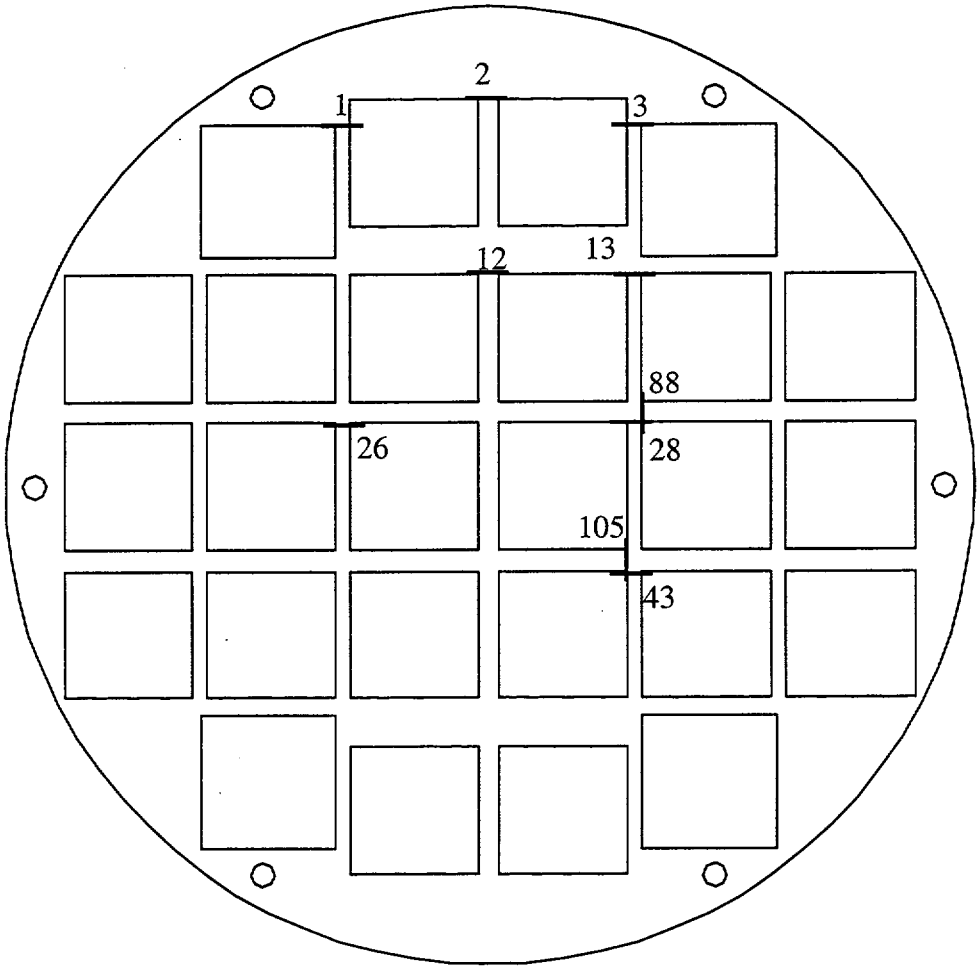


Table 2.6.16.8-1 Summary of Maximum CY-MPC Support Disk P + Q Stresses for 1-Foot Side Drop

Section	Margin of Safety
0° Basket Orientation	
1	4.08
3	4.18
9	4.87
7	4.88
11	5.49
38° Basket Orientation	
3	1.95
13	1.95
28	2.03
1	2.13
2	2.20
63° Basket Orientation	
43	2.10
106	2.22
28	2.27
13	2.38
3	2.39
90° Basket Orientation	
129	3.80
108	4.45
90	4.50
24	4.83
44	4.85

Table 2.6.16.8-2 P+Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 0° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	-25.80	0.90	0.20	25.80	131.10	4.08
3	-25.30	0.80	-0.20	25.30	131.10	4.18
9	-22.10	0.00	-0.30	22.10	129.70	4.87
7	-22.00	1.10	0.20	22.00	129.70	4.88
11	-14.60	-5.20	1.20	19.90	129.40	5.49
13	-14.50	-5.10	-1.20	19.70	129.40	5.55
66	-16.20	7.60	-2.40	16.80	129.40	6.70
73	-16.00	7.30	2.30	16.60	129.40	6.80
2	-11.50	-4.10	1.10	15.70	132.10	7.39
81	-14.40	9.30	-1.60	14.90	127.90	7.59
69	-6.30	-8.40	1.70	15.10	129.50	7.60
5	-15.20	0.00	0.00	15.20	130.90	7.61
70	-6.30	-8.40	-1.70	15.00	129.50	7.61
21	-13.90	10.20	-2.10	14.80	128.00	7.63
88	-14.30	9.10	1.60	14.80	127.90	7.65
131	-13.50	6.00	3.70	15.00	130.10	7.67
23	-13.90	10.10	2.00	14.70	128.00	7.68
12	-9.50	-5.20	0.90	14.80	129.50	7.76
4	-13.80	0.00	-0.70	13.90	130.40	8.37
67	-10.60	-3.10	0.40	13.80	129.40	8.38
72	-10.50	-3.30	-0.40	13.80	129.40	8.39
6	-13.70	0.00	0.70	13.80	130.40	8.43
8	-11.90	8.20	-3.20	13.70	129.80	8.44
82	-8.60	-4.20	-0.10	12.90	128.00	8.95
26	-11.50	-1.30	0.50	12.80	127.90	8.99
87	-8.50	-4.20	0.10	12.70	128.00	9.09
28	-11.30	-1.30	-0.50	12.70	127.90	9.11
27	-8.50	-3.90	-0.20	12.40	128.00	9.31
99	-11.50	9.90	-1.20	12.20	127.50	9.48
124	-7.80	7.00	-4.90	12.30	130.30	9.58

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.8-3 P + Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
3	-43.60	14.90	-5.20	44.50	131.10	1.95
13	-43.90	13.40	1.10	43.90	129.40	1.95
28	-42.00	22.80	1.90	42.20	127.90	2.03
1	-41.60	1.80	3.20	41.80	131.10	2.13
2	-41.20	8.40	-1.20	41.20	132.10	2.20
88	-39.30	15.20	0.80	39.30	127.90	2.26
43	-38.40	22.20	2.50	38.70	127.50	2.29
12	-38.90	12.70	-0.40	38.90	129.50	2.33
105	-37.70	28.10	1.50	37.90	127.50	2.36
26	-37.20	27.30	2.30	37.70	127.90	2.40
82	-37.40	21.50	2.00	37.60	128.00	2.40
100	-37.00	20.50	2.50	37.30	127.50	2.42
87	-37.20	27.80	1.10	37.30	128.00	2.43
73	-37.30	5.40	-3.30	37.60	129.40	2.44
99	36.70	-17.60	2.40	37.00	127.50	2.45
41	-36.20	26.30	2.70	36.90	127.50	2.45
106	-36.80	15.40	1.60	36.90	127.50	2.46
81	35.50	-15.30	2.60	35.80	127.90	2.57
52	-35.30	14.40	-0.30	35.30	127.50	2.61
42	-34.60	30.50	1.30	35.00	127.50	2.64
11	-35.30	14.20	1.10	35.40	129.40	2.66
29	-34.70	12.60	0.70	34.80	127.90	2.68
38	-34.40	30.50	0.70	34.50	127.50	2.70
70	-34.80	5.00	0.60	34.80	129.50	2.72
103	-33.10	25.30	3.00	34.20	127.50	2.73
9	-34.60	13.40	-1.40	34.70	129.70	2.74
84	-31.80	30.50	2.90	34.10	128.00	2.75
23	-33.70	29.70	0.10	33.70	128.00	2.80
102	-28.70	29.90	4.00	33.40	127.50	2.82
22	-30.30	33.40	0.60	33.50	128.10	2.82

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.8-4 P + Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 63° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
43	-40.90	28.80	1.90	41.20	127.50	2.10
106	-39.60	22.00	1.00	39.60	127.50	2.22
28	-39.00	26.90	1.20	39.20	127.90	2.27
13	-38.20	18.20	0.60	38.20	129.40	2.38
3	-37.70	15.80	-4.70	38.60	131.10	2.39
105	37.10	-15.50	2.70	37.40	127.50	2.41
88	-37.30	20.60	0.30	37.30	127.90	2.43
41	36.20	-20.20	2.80	36.70	127.50	2.47
100	-36.20	22.30	1.40	36.40	127.50	2.51
44	-35.60	19.00	0.80	35.60	127.50	2.58
99	35.40	-12.50	1.90	35.50	127.50	2.59
42	-34.30	34.00	0.70	34.90	127.50	2.66
103	-33.20	28.90	2.30	34.20	127.50	2.73
73	-34.00	12.10	-2.90	34.40	129.40	2.76
29	-33.80	14.90	0.40	33.90	127.90	2.78
52	-33.50	11.80	0.50	33.50	127.50	2.81
26	32.70	-16.40	2.60	33.10	127.90	2.87
102	32.00	-20.70	3.30	32.90	127.50	2.88
111	-10.70	32.10	-2.80	32.50	127.50	2.93
109	-32.30	13.80	1.30	32.40	127.50	2.94
82	-32.30	20.90	0.80	32.40	128.00	2.95
87	31.80	-12.40	2.60	32.20	128.00	2.98
129	-19.30	19.70	-11.90	31.40	127.50	3.06
81	31.40	-9.00	1.60	31.50	127.90	3.06
53	-31.00	14.10	0.40	31.00	127.50	3.11
108	30.30	-9.90	3.10	30.70	127.50	3.15
38	-28.30	29.60	1.50	30.60	127.50	3.17
51	-29.50	12.90	2.50	29.90	127.50	3.27
37	-18.60	29.40	2.10	29.80	127.50	3.28
40	29.50	-11.20	1.20	29.60	127.50	3.31

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.6.16.8-5 P + Q Stresses for CY-MPC Support Disk 1-Foot Side Drop, 90° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
129	-13.90	18.90	-9.80	26.60	127.50	3.80
108	15.00	8.40	-0.30	23.40	127.50	4.45
90	12.80	10.40	0.60	23.20	127.90	4.50
24	17.30	4.60	0.10	21.90	127.90	4.83
44	19.30	2.50	0.00	21.80	127.50	4.85
29	11.30	7.10	-0.60	18.40	127.90	5.93
105	12.00	5.70	-0.20	17.70	127.50	6.20
39	8.80	8.90	0.70	17.70	127.50	6.21
87	9.80	7.20	0.40	17.00	128.00	6.51
20	-16.80	9.00	1.20	17.00	127.90	6.54
40	-16.50	7.80	-1.10	16.60	127.50	6.68
111	-5.80	14.80	-3.00	15.80	127.50	7.08
43	-13.90	14.70	-1.20	15.50	127.50	7.21
110	-0.10	15.40	-0.30	15.40	127.50	7.30
125	9.60	-8.70	5.90	15.10	128.70	7.52
130	-8.90	12.60	3.90	15.10	128.70	7.53
23	13.10	1.70	-0.60	14.80	128.00	7.64
91	-8.50	14.30	1.30	14.60	127.90	7.76
21	-14.20	11.60	1.10	14.60	128.00	7.78
42	-12.00	13.60	-1.40	14.50	127.50	7.82
109	-10.50	14.20	-1.00	14.40	127.50	7.82
106	-12.10	12.50	-2.00	14.30	127.50	7.91
41	-13.90	11.40	-1.10	14.30	127.50	7.91
92	-0.10	14.30	0.20	14.30	127.80	7.94
126	9.30	-7.80	-5.50	14.10	127.50	8.06
93	-4.70	12.90	3.30	14.10	127.70	8.08
28	7.50	6.40	0.30	13.90	127.90	8.23
79	-13.40	5.80	1.50	13.70	127.90	8.34
22	-11.20	12.70	1.50	13.60	128.10	8.39
54	7.50	5.80	0.90	13.50	127.50	8.46

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

2.6.16.9 CY-MPC Support Disk Shear Stresses for 1-Foot Drop

The evaluation of the maximum shear stress in the support disk utilizes the membrane values of the stress intensity due to primary loading, which were evaluated for end and side drop conditions. The maximum membrane stress intensity is 31.9 ksi for section 73 (see Table 2.6.16.7-3). Therefore, the maximum shear stress is 31.9/2 or 15.95 ksi. In accordance with ASME Code, Section III, Division 1, Subsection NG, the Level A allowable for shear stress is 0.6 S_m. Using the bounding temperature of 650°F, S_m for Type 17-4 PH stainless steel is 41.9 ksi, the margin of safety is:

M.S. $= 25.14/15.9 - 1 = .58$

2.6.16.10 Bearing Stress - Basket Contact with Canister Shell – CY-MPC

For the bearing stress (S_{br}) acting along the basket disk-canister shell interface, an angular contact of 30 degrees is conservatively considered based on ANSYS gap element status (at a diameter of 69.15 inches). The load considered to be acting on the disk is the total contents weight (56 kips, which is conservative) times the deceleration (20 g) divided between 28 disks. The bearing area is considered to be the 0.5-inch thick disk and the contact area corresponding to a 30-degree angular contact.

$S_{br} = (56/28)(20)/[(.5)(\pi)(69.15)(30/360)] = 4.4$ ksi

The allowable bearing stress is the yield stress, which for 17-4PH stainless steel at a temperature of 400°F, is 89.6 ksi. The maximum canister shell temperature for transport conditions is 351°F. The margin of safety is:

M.S. $= 89.6/ 4.4 - 1 = 19.3$

2.6.16.11 CY-MPC Fuel Basket Weldment Analysis for 1-Foot End Drop

The responses of the top and bottom weldment plates of the fuel basket assembly to a 1-foot end drop in conjunction with the thermal expansion stress are also evaluated. The top and bottom weldment plates are 0.5-inch thick plates of Type 304 stainless steel. The weldments support their own weight plus the weight of 26 fuel assembly tubes. A finite element analysis is performed for both plates, since the support for each weldment is different due to the location of the support ribs for each. Both models use the SHELL63 element, which permits out of plane loading. Figures 2.6.16.11-1 and 2.6.16.11-2 show the finite element models for the weldments. The ribs supporting the disk were also represented by SHELL63. Evenly distributed nodal forces around the periphery of the fuel assembly slot represent the force on the weldment from each fuel tube. The application of the nodal loads at the slot periphery is accurate since the tube weight is transmitted to the edge of the slot, which provides support to the fuel tubes in the end drop condition.

This analysis demonstrates that the weldment design satisfies the primary membrane plus bending ($P_m + P_b$) and the primary and secondary ($P + Q$) stress criteria. For the end drop, the primary membrane stresses in the weldments are small. An analysis including the thermal expansion stresses is also performed using a bounding temperature distribution throughout the weldment. The determination of the weldment temperatures is discussed in Chapter 3.

The margins of safety are calculated as:

$$M.S. = [(P_m + P_b) / 1.5\ S_m] - 1$$

or

$$M.S. = [(P_m + P_b + Q) / 3\ S_m] - 1$$

The margins of safety are conservatively evaluated at the maximum temperature of 500°F. The calculated temperatures are shown in Table 2.6.16.11-1. The weldments are shown to satisfy the stress criteria in ASME Code, Section III Division I, Subsection NG.

Figure 2.6.16.11-1 Finite Element Model of the CY-MPC Top Weldment Plate

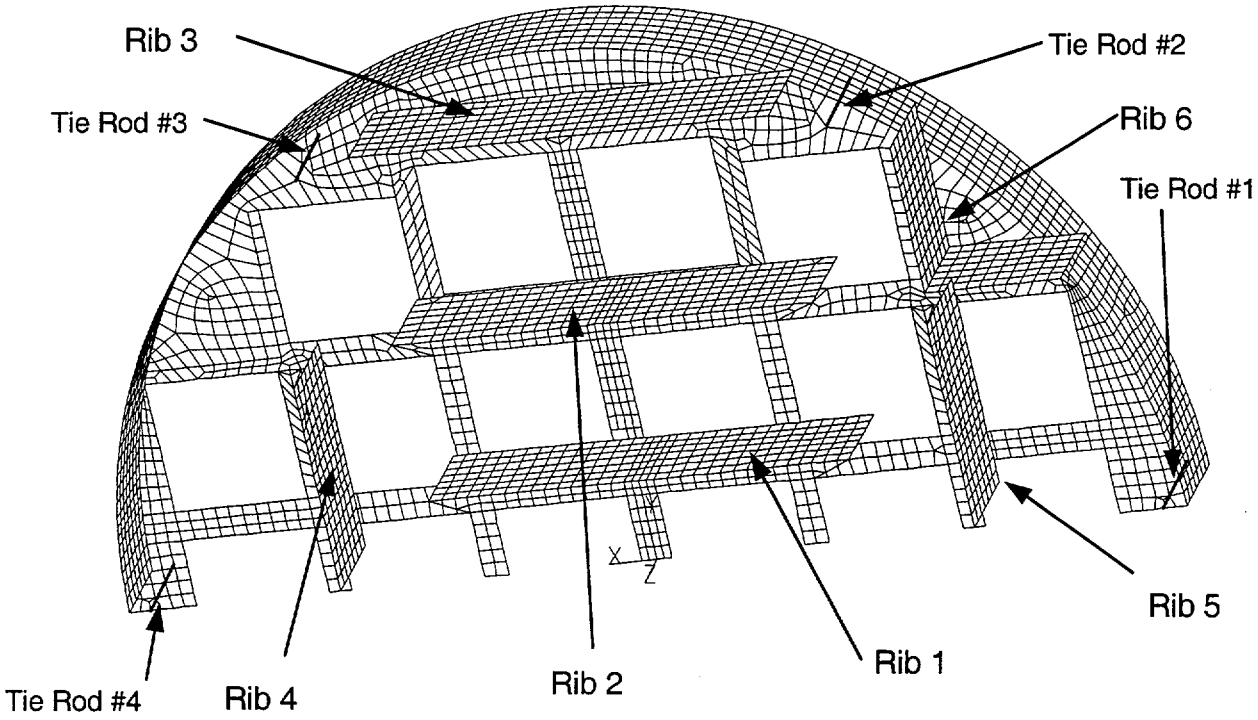


Figure 2.6.16.11-2 Finite Element Model of the CY-MPC Bottom Weldment Plate

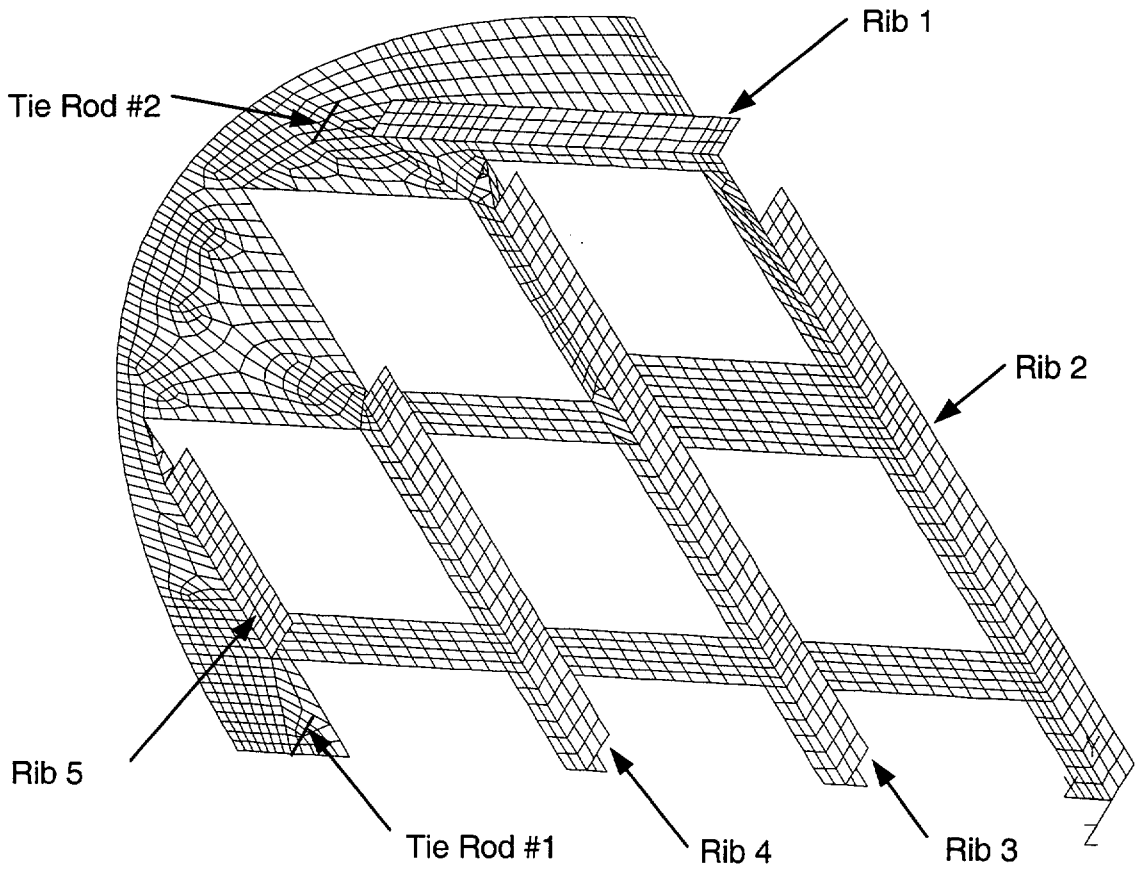


Table 2.6.16.11-1 Minimum Margins of Safety for the CY-MPC Top/Bottom Weldments for a 1-Foot End Drop With and Without Thermal Stresses

Component/Condition	$P_m + P_b$ (ksi)	Nodal Temp. (°F)	$1.5S_m$@500°F (ksi)	M.S.
Top Weldment/1-ft. End Drop	19.21	247	26.25	+0.37
Bottom Weldment/1-ft. End Drop	15.73	221	26.25	+0.67
Component/Condition	**$P_m + P_b + Q$ (ksi)**	**Nodal Temp. (°F)**	**$3S_m$ (ksi)**	**M.S.**
Top Weldment/1-ft. End Drop	34.26	235	52.50	+0.53
Bottom Weldment/1-ft. End Drop	22.83	200	52.50	+1.3

2.6.16.12 CY-MPC Fuel Basket Support Disk - Buckling Evaluation

The CY-MPC fuel basket support disk is subjected to compressive and/or inertia loads during a 1-foot drop of the NAC-STC cask onto an unyielding surface. Depending on the cask orientation for the 1-foot drop impact, the support disk may have both in-plane and out-of-plane loads applied to it. The in-plane loads (basket side impact component) apply compressive forces and in-plane (strong axis) bending moments on the support disk and the out-of-plane inertial loads (basket end-impact component) produce out-of-plane (weak axis) bending moments on the support disk. Buckling of the support disk is evaluated in accordance with the methods and acceptance criteria of NUREG/CR-6322.

Buckling analysis was completed only for the 38° basket orientation because this is the worst case angle (see Section 2.6.16.7). The minimum margin of safety is +1.23, which occurs at section number 13. The results for the 20 worst-case sections are summarized in Table 2.6.16.12-1.

Table 2.6.16.12-1 NUREG/CR 6322 Buckling Analysis for the CY-MPC Support Disk 1-Foot Side Drop, 38° Basket Orientation

Sect.	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
13	6.50	43.81	48.30	4.48	13.28	13.02	1.23	1.38
3	5.59	44.51	49.07	4.47	13.49	13.22	1.38	1.53
28	3.93	43.13	47.54	4.49	13.07	12.83	1.54	1.68
23	4.97	43.18	47.59	3.63	13.09	12.84	1.78	1.95
29	3.46	38.51	43.17	3.09	10.79	10.50	1.90	2.10
12	2.99	62.28	65.94	8.49	24.73	24.73	1.93	1.97
38	3.52	42.86	47.23	3.82	12.99	12.75	1.93	2.09
9	4.67	43.97	48.47	3.45	13.33	13.07	1.99	2.17
43	2.50	42.86	47.23	4.01	12.99	12.75	2.05	2.18
2	3.50	63.85	67.61	7.86	25.36	25.36	2.13	2.18
1	1.91	44.51	49.07	4.20	13.49	13.22	2.17	2.30
14	4.22	39.06	43.80	2.29	10.95	10.64	2.39	2.66
39	3.09	38.31	42.93	2.50	10.73	10.44	2.47	2.71
22	3.01	61.33	64.93	6.61	24.35	24.35	2.56	2.62
44	2.43	38.31	42.93	2.57	10.73	10.44	2.63	2.86
24	4.21	38.55	43.21	1.94	10.80	10.51	2.71	3.01
52	1.15	60.84	64.40	7.10	24.15	24.15	2.71	2.74
53	1.18	42.86	47.23	3.58	12.99	12.75	2.74	2.86
27	2.35	61.26	64.85	6.23	24.32	24.32	2.89	2.95
42	1.47	60.84	64.40	6.58	24.15	24.15	2.90	2.94

2.6.16.13 Stress Evaluation of the CY-MPC Support Disk for 1-Foot Oblique Drop

This section documents the methodology used to calculate the stresses due to oblique impacts of the transport cask. The results show that the stress criteria are met for all oblique conditions. Note that the methodology used for the oblique drop evaluation is very conservative since the g loads decrease significantly for oblique drops (see Section 2.6.7.4).

To evaluate oblique impacts, the stress components (i.e., S_x, S_y, S_{xy}) are combined from the side drop and end drop cases for both the 0° the 38° basket drop orientations (Figure 2.6.16.1-1). The stresses are combined according to the following cask drop angles: ϕ = 0°, 24°, 30°, 45°, 60°, 73°, 75°, 77°, 80°, 83°, 85°, 88° and 90°. Note that the 0° and 90° cask drop angles are equivalent to the end- and side- drop cases, respectively. The normal stresses (S_x and S_y) and the shear stress (S_{xy}) for a drop with an angle of ϕ (Figure 2.6.16.2-3) are calculated using the following equations:

$$S_{x(\phi)} = S_{x(end)}Cos\phi + S_{x(side)}Sin\phi ,$$

$$S_{y(\phi)} = S_{y(end)}Cos\phi + S_{y(side)}Sin\phi ,$$

$$S_{xy(\phi)} = S_{xy(end)}Cos\phi + S_{xy(side)}Sin\phi ,$$

where:

$S_{x(end)}$, $S_{y(end)}$, and $S_{xy(end)}$ are the sectional stresses resulting from the Support Disk End Drop Model, and $S_{x(side)}$, $S_{y(side)}$, and $S_{xy(side)}$ are the section stresses resulting from the Support Disk Side Drop Model.

Oblique principal stresses (i.e., S_1, S_2) are calculated by using the following equation:

$$S_1, S_2 = \frac{S_{x(\phi)} + S_{y(\phi)}}{2} \pm \sqrt{\left(\frac{S_{x(\phi)} - S_{y(\phi)}}{2}\right)^2 + S_{xy(\phi)}^2}$$

Once the oblique principle stresses are calculated, new stress intensities (SI) and margins of safety can be calculated. A summary of the maximum stress intensities in the 1-foot oblique drop conditions is shown below. Note that the 0° and 90° cask drop angles, equivalent to the end

drop and side drop, are the worst case conditions for the 0° and 38° basket orientations, respectively.

Stress State[1]	Section[2]	Cask Drop Angle (°)[3]	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
0° BASKET DROP ORIENTATION[4]								
P_m	2	90	-12.70	-6.20	0.00	18.80	44.00	1.34
P_m+P_b	61	0	31.40	-6.10	11.90	36.20	63.80	0.76
38° BASKET DROP ORIENTATION[4]								
P_m	73	88 & 90	-31.70	2.10	2.50	31.90	43.10	0.35
P_m+P_b	13	88 & 90	-56.30	19.50	1.90	56.40	64.70	0.15

Notes:

1. P_m = Primary Membrane Stress, $P_m + P_b$ = Primary Membrane + Bending Stress.
2. See Figure 2.6.16.2-5 for section locations.
3. See Figure 2.6.16.2-3 for definition of cask drop angle.
4. See Figure 2.6.16.1-1 for definition of basket drop orientation.

2.6.16.14 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot Oblique Drop Load Condition

The thermal expansion loads described in Section 2.6.16.3 are applied to the finite element model simultaneously with the 20g oblique drop loads described in Section 2.6.16.13 to produce a combined thermal expansion plus oblique impact loading. A summary of the maximum stress intensities in the thermal plus 1-foot oblique drop conditions is shown below. Note that the 0° cask drop angle, equivalent to the end drop, is the worst case condition for both basket orientations considered.

Basket Drop Orientation Angle (°)[4]	Stress State[1]	Section[2]	Cask Drop Angle (°)[3]	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
0	P + Q	61	0	30.40	-5.80	11.80	35.10	127.50	2.63
38	P + Q	1	45	42.30	-15.90	-10.20	45.80	131.1	1.86

Notes:

1. P_m = Primary Membrane Stress, $P_m + P_b$ = Primary Membrane + Bending Stress.
2. See Figure 2.6.16.2-5 for section locations.
3. See Figure 2.6.16.2-3 for definition of cask drop angle.
4. See Figure 2.6.16.1-1 for definition of basket drop orientation.

Tube Array Weldment Weld Analysis

The tube array weldment tubes are welded together, structurally, around the outer perimeter only; the outer perimeter seams are overlapped by plates and angles that are welded to the tubes by quarter-inch full length fillet welds. The interior joints may be tack-welded only for assembly purposes. These tack welds are not considered in this model. The weld loads are obtained from the nodal forces at the coupled nodes in the model. The two orthogonal force components are combined by SRSS to calculate total weld force for a unit length weld. The weld stress and safety margins are presented in Table 2.6.19-3 for the governing drop orientation of 75°. The minimum margin of safety is +0.29. The maximum temperature of 380°F from all the weld locations is used to calculate allowable stresses at the weld locations. Allowable stresses are based on Table NF-3324.5(a)-1 of the ASME Code. The allowable weld force is:

$$F_{allow} = 0.4(Sy)(0.7071 \times 0.25) = 0.4 \times 21060 \times 0.7071 \times 0.25 = 1490 \text{ lbs/in}$$

Shield Shell Weldment

The shield shell weldment is evaluated to provide support to the tube array and maintain structural integrity during normal conditions of transport.

Shield Shell Weldment End Drop Analysis

During an end drop the entire weight of the shield shell weldment applies a compressive load at its base. The shield shell weldment consists of the cylindrical shell and the 12 longitudinal ribs. The weight of the assembly is approximately 15,550 lbs., to account for additional hardware. A total weight of 15,700 will be used in the evaluation.

The cross-sectional area of the shell weldment at the base is:

$$A = \frac{\pi}{4} \times \left[64^2 - 60.5^2\right] = 437.8 \text{ in}^2 \quad \text{(Area of ribs is neglected)}$$

The stress at the base of the assembly is:

$$S_s = \frac{20 \times 15{,}700}{437.8} = 717 \text{ psi}$$

The maximum temperature for the shell is 272°F; the allowable stress, S_m at 300°F is 20,000 psi.

Therefore, the margin of safety is:

$$MS = \frac{20{,}000}{717} - 1 = +\text{large}$$

Shield Shell Weldment Side Drop Analysis

For a side-drop scenario, a two-dimensional finite element model of the shield shell assembly constructed, using ANSYS PLANE42 elements, as shown in Figure 2.6.19-5. The model represents a cross section of the shield shell assembly.

Similar to the evaluation for the tube array, four side drop orientations (45°, 60°, 75° and 90°) are considered. The boundary conditions for the finite element model for the 75° drop orientation are shown in Figure 2.6.19-6, as an example. The applied loads represent the forces transferred from the tube array at the locations where the tube array is in contact with the shield weldment during a 1-foot side drop condition (20g). A conservative temperature of 300°F is used to determine the material properties and the allowable stresses.

The analysis results indicate that the governing case corresponds to the drop orientation of 75°. The stress results for this drop orientation are summarized in Tables 2.6.19-4 and 2.6.19-5 for the P_m and P_m+P_b stress respectively. The minimum margin of safety is +5.65 for the P_m stress and +3.67 for the P_m+P_b stress. The locations of the sections with top four P_m+P_b stresses are shown in Figure 2.6.19-7.

During the side drop, the only contact between the basket and the canister is along the entire length of the longitudinal ribs. The bearing stress is conservatively calculated as the entire load being applied through one rib.

The total weight of the basket is 30,413 lbs and the maximum waste weight is 18,742 lbs, and considering an acceleration of 20g, the maximum load is:

$$F = (30{,}413 + 18{,}742) \times 20 = 983{,}100 \text{ lbs.}$$ Use 1,000,000 lbs for analysis.

The area of contact is:

$$A = 141.5 \times 1.25 = 176.9 \text{ in}^2$$

The bearing stress is:

$$f_b = \frac{1{,}000{,}000}{176.9} = 5{,}654 \text{ psi}$$

The yield strength (S_y) of SA-240 Type 304 stainless steel at 300°F is 22.5 ksi, and the margin of safety is:

$$MS = \frac{S_y}{f_b} - 1 = \frac{22{,}500}{5{,}654} - 1 = +2.95$$

Shield Shell Weldment Side Drop Analysis

The longitudinal ribs are connected to the shield shell by 3/16" partial penetration groove welds along the entire length of the shell.

The impact load is transmitted from the ribs to the shell across the two connecting welds on each rib. Subsection NF-3226.2 of the ASME code provides with the requirements for the partial penetration welds to meet the same requirements as for the base metal. Conservatively, the stresses across the weld are treated as membrane stresses and are subject to the stress limit of S_m. For the analyzed drops the minimum number of ribs in contact with the canister is two; therefore, the total load will be resisted by 4 welds. The total applied load of 1,000,000 lbs. is uniformly distributed across the section of each weld. The area of the welds joining the rib to the shell is:

$$A = 4 \times 141.5 \times \frac{3}{16} = 106.2 \text{ in}^2$$

The average stress is:

$$S_{average} = \frac{1{,}000{,}000}{106.2} = 9{,}416 \text{ psi}$$

The membrane strength (S_m) of SA-240 Type 304 stainless steel at 300°F is 20 ksi. The margin of safety is:

$$MS = \frac{S_m}{S_{average}} - 1 = \frac{20{,}000}{9{,}416} - 1 = 1.12$$

Figure 2.6.19-1 Yankee-MPC GTCC Basket Assembly

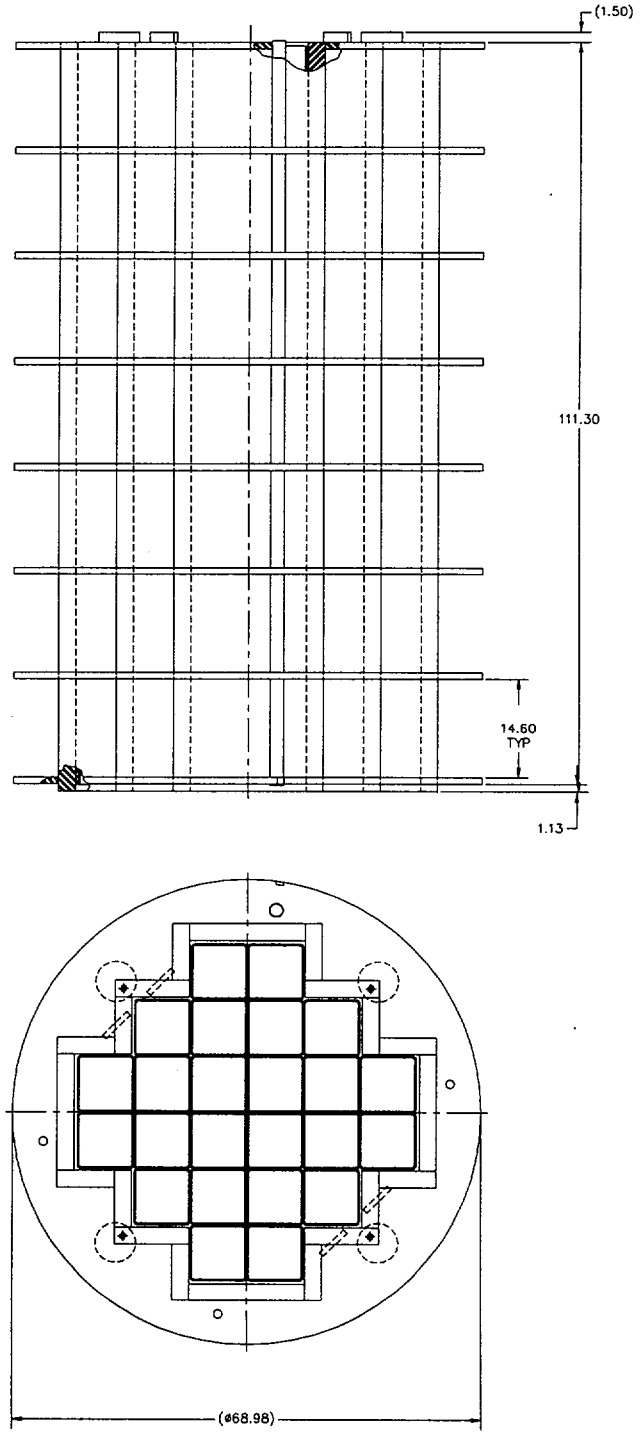


Figure 2.6.19-6 CY-MPC GTCC Basket Shield Shell Assembly Loading and Boundary Conditions (75° Impact Orientation Shown) – Side Drop

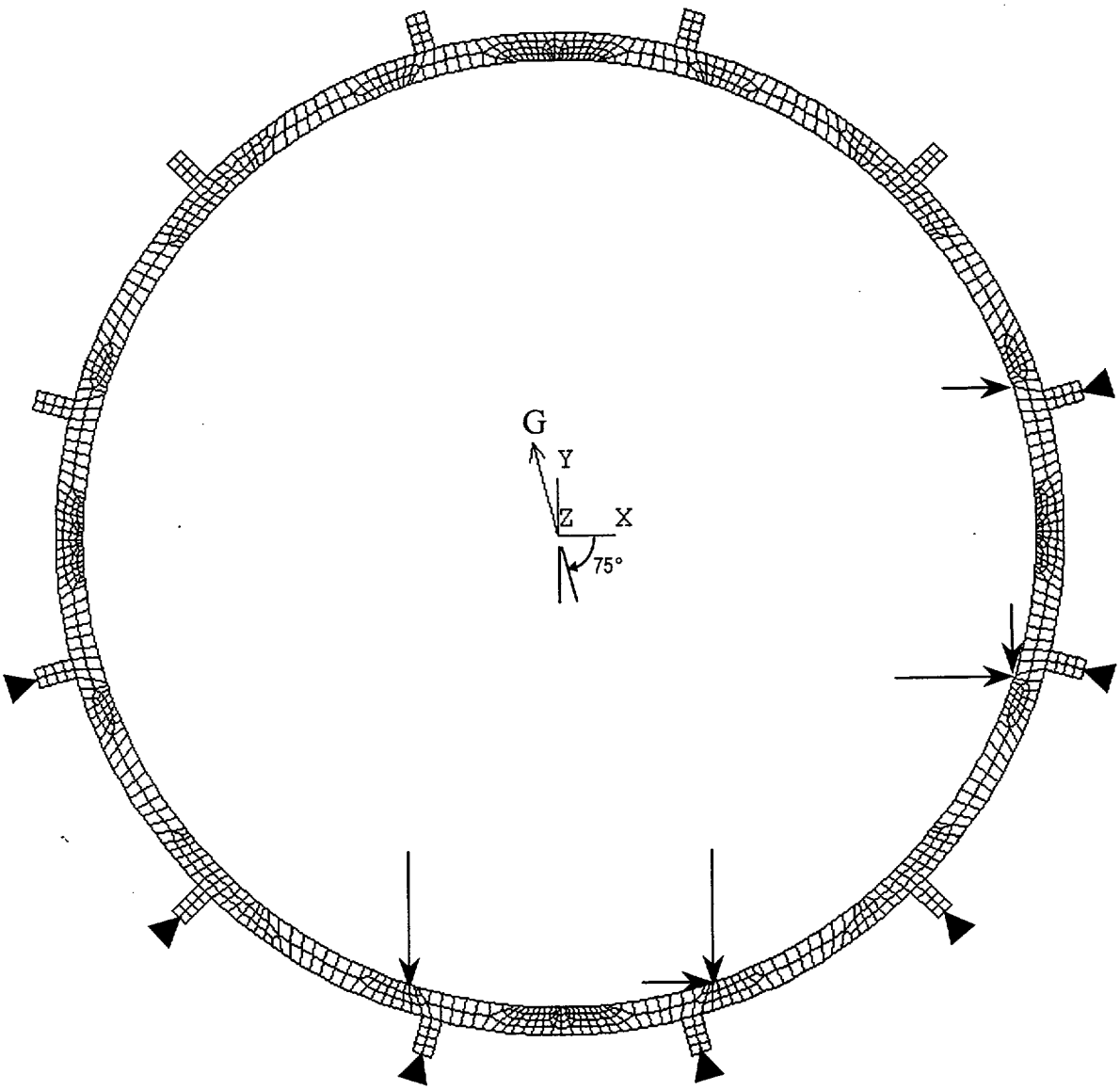


Figure 2.6.19-7 CY-MPC GTCC Shield Shell – Section Locations of Top Four P_m+P_b Stresses

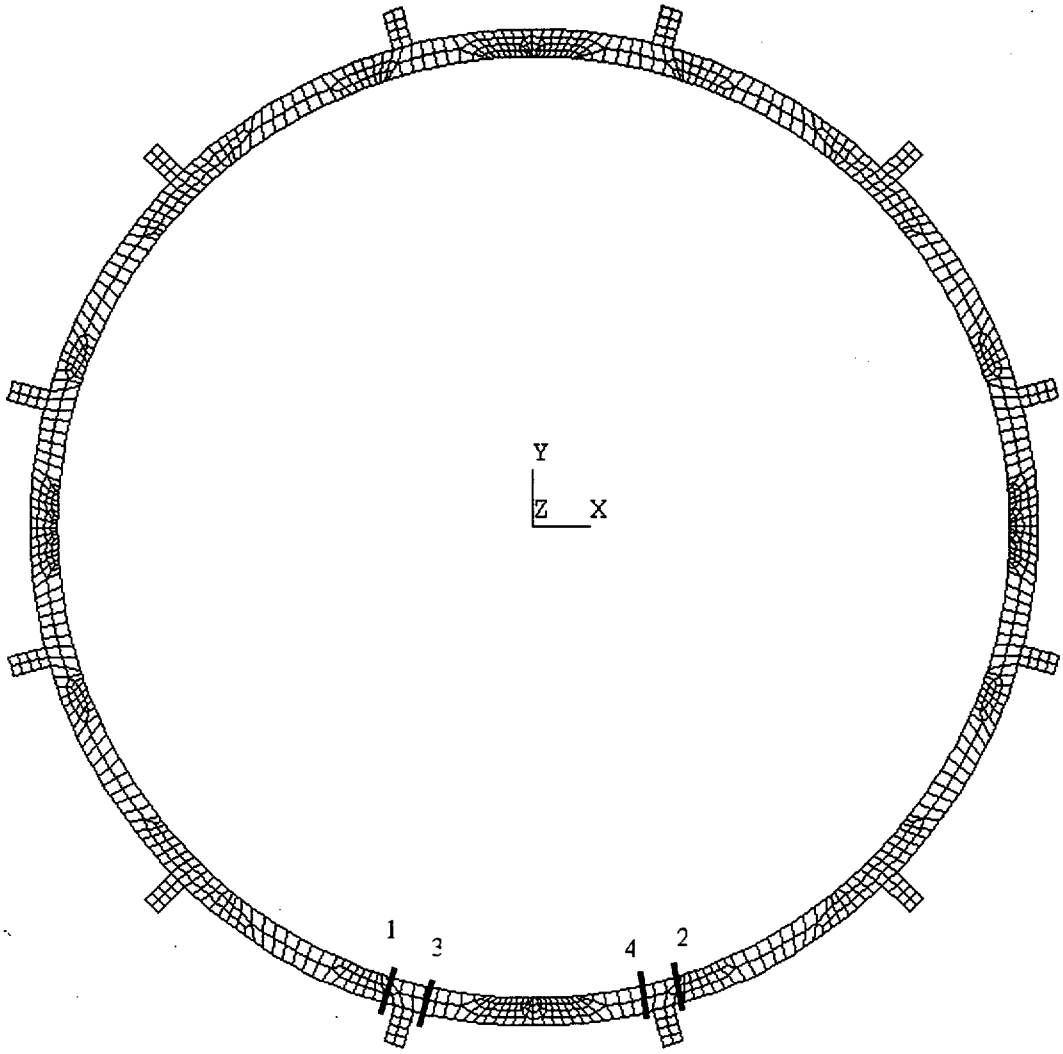


Table 2.6.19-1 CY-MPC GTCC Tube Array Weldment P_m Stress Summary – 75° Side Drop, Normal Condition

Sec	Principal Stress Components (psi)			Stress Intensity (psi)	Allowable Stress (psi)	Margin of Safety
	S1	S2	S3			
1	334.4	0.0	-3996.0	4330.0	18986	3.38
2	685.7	0.0	-1604.0	2290.0	18173	6.94
3	424.4	0.0	-3321.0	3746.0	18986	4.07
4	485.2	0.0	-3523.0	4008.0	18388	3.59
5	876.0	0.0	-246.9	1123.0	18395	15.38

Table 2.6.19-2 CY-MPC GTCC Tube Array Weldment P_m+P_b Stress Summary – 75° Side Drop, Normal Condition

Sec	Principal Stress Components (psi)			Stress Intensity (psi)	Allowable Stress (psi)	Margin of Safety
	S1	S2	S3			
1	1004.0	0.0	-23210.0	24220.0	28479	0.18
2	1477.0	0.0	-20820.0	22300.0	27260	0.22
3	1084.0	0.0	-20480.0	21560.0	28479	0.32
4	1141.0	0.0	-19700.0	20840.0	27582	0.32
5	1573.0	0.0	-18470.0	20040.0	27593	0.38

* See Figure 2.6.19-4 for Section Locations.

Table 2.6.19-3 CY-MPC GTCC Tube Array Weld Evaluation - 75° Side Drop, Normal Condition

Weld Location*	Fx	Fy	Weld Force (lbs)	Allowable (lbs)	Margin
17	206.4	-1205.9	1223.4	1490	0.22
19	-900.0	-595.7	1079.2	1490	0.38
18	915.3	-471.4	1029.5	1490	0.45
9	617.4	543.5	822.5	1490	0.81
10	-380.8	-463.8	600.1	1490	1.48
8	-203.9	-485.1	526.2	1490	1.83
24	364.3	354.7	508.4	1490	1.93
20	85.5	-492.1	499.5	1490	1.98
16	-428.9	171.4	461.9	1490	2.23
11	396.9	124.0	415.9	1490	2.58
1	39.6	-369.9	372.0	1490	3.01
2	350.0	-48.4	353.3	1490	3.22
23	-87.9	-327.7	339.3	1490	3.39
15	64.5	-308.8	315.4	1490	3.72
14	-279.8	60.0	286.2	1490	4.21
4	-180.9	140.2	228.9	1490	+large
3	-15.8	115.9	117.0	1490	+large
12	-85.8	-78.0	116.0	1490	+large
5	72.8	-63.0	96.2	1490	+large
21	41.7	65.5	77.6	1490	+large
22	14.6	57.4	59.2	1490	+large
6	56.6	-7.5	57.1	1490	+large
7	-33.7	-7.3	34.5	1490	+large
13	-5.3	-26.4	26.9	1490	+large

* See Figure 2.6.19-3 for Weld Locations

2.7.1.1 Thirty-Foot End Drop

The NAC-STC is structurally evaluated for the hypothetical accident 30-foot end drop condition in accordance with the requirements of 10 CFR 71.73(c)(1). In this evaluation, the directly loaded NAC-STC (equipped with an impact limiter over each end) falls through a distance of 30 feet onto a flat, unyielding, horizontal surface. The cask strikes the surface in a vertical position; consequently, an end impact on the bottom end or top end of the cask occurs. The types of loading involved in an end drop accident are closure lid bolt preload, internal pressure, thermal, impact load, and inertial body load. There are six credible end impact conditions to be considered, according to Regulatory Guide 7.8:

1. Top end drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

2. Top end drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.

3. Top end drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

4. Bottom end drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

5. Bottom end drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.

6. Bottom end drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

2.7.1.1.1 Thirty-Foot End Drop—NAC STC Directly Loaded and Yankee-MPC Configurations

The finite element analysis method is utilized to perform the end drop stress evaluations for the NAC-STC. The end drop accident condition can be analyzed using a two-dimensional axisymmetric model, because of the symmetry of both the cask structure and the loads involved in the end drop case. The cask is modeled as an axisymmetric structure using ANSYS STIF42

isoparametric elements. A detailed description of the two-dimensional finite element model of the NAC-STC is provided in Section 2.10.2.1.1.

During an impact event, the cask body will experience a vertical deceleration. Considering the cask as a free body, the impact limiter will apply the load to the cask end to produce the deceleration. Since the deceleration represents an amplification factor for the inertial loading of the cask, the equivalent static method is adopted to perform the impact evaluations. The analyses consider the behavior of the cask to be linearly elastic. Additionally, the fabrication stresses are considered to be negligible (Section 2.6.11).

Five categories of load--closure lid bolt preload, internal pressure, thermal, impact, and inertial body loads--are considered on the cask:

1. Closure lid bolt preload - The required bolt preload on the inner lid bolts is 115,066 pounds per bolt. For the outer lid bolts, the bolt preload is 36,810 pounds per bolt. Individual bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3. The bolts are modeled as beam (ANSYS STIF3) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. Pressures of 50 psig and 12 psig are applied on the interior surfaces of the cask cavity for the hot ambient and cold ambient cases, respectively. These pressures envelope the calculated pressures for cask configurations - directly loaded fuel (12 psig), Yankee-MPC canistered fuel (11.3 psig), and Yankee-MPC canistered GTCC waste (<11.3 psig).

3. Thermal - The heat transfer analyses performed in Sections 3.4.2 and 3.4.3 determine the cask temperature distributions for the following three combinations of ambient temperature, heat load, and solar insolation for directly loaded fuel.

   Condition 1. 100°F ambient temperature, with maximum decay heat load, and maximum solar insolation.

drop. The minimum margin of safety for the top end drop condition is found to be +4.8, as documented in Table 2.7.1.1-3. The minimum margin of safety for the bottom end drop condition is found to be +3.4, as documented in Table 2.7.1.1-5. The stresses that occur at the center of the end plate and lids are artificially high due to the presence of a small hole modeled in the ends (ANSYS modeling technique) and are ignored in the results post-processing.

The NAC-STC maintains its containment capability and therefore satisfies the requirements of 10 CFR 71.73 for the hypothetical accident 30-foot side drop condition for the CY-MPC fuel configuration, which envelopes the canistered fuel and canistered GTCC waste configurations for the 30-foot side drop conditions

Figure 2.7.1.1-1 Location of Sections for CY-MPC Configuration Stress Evaluation

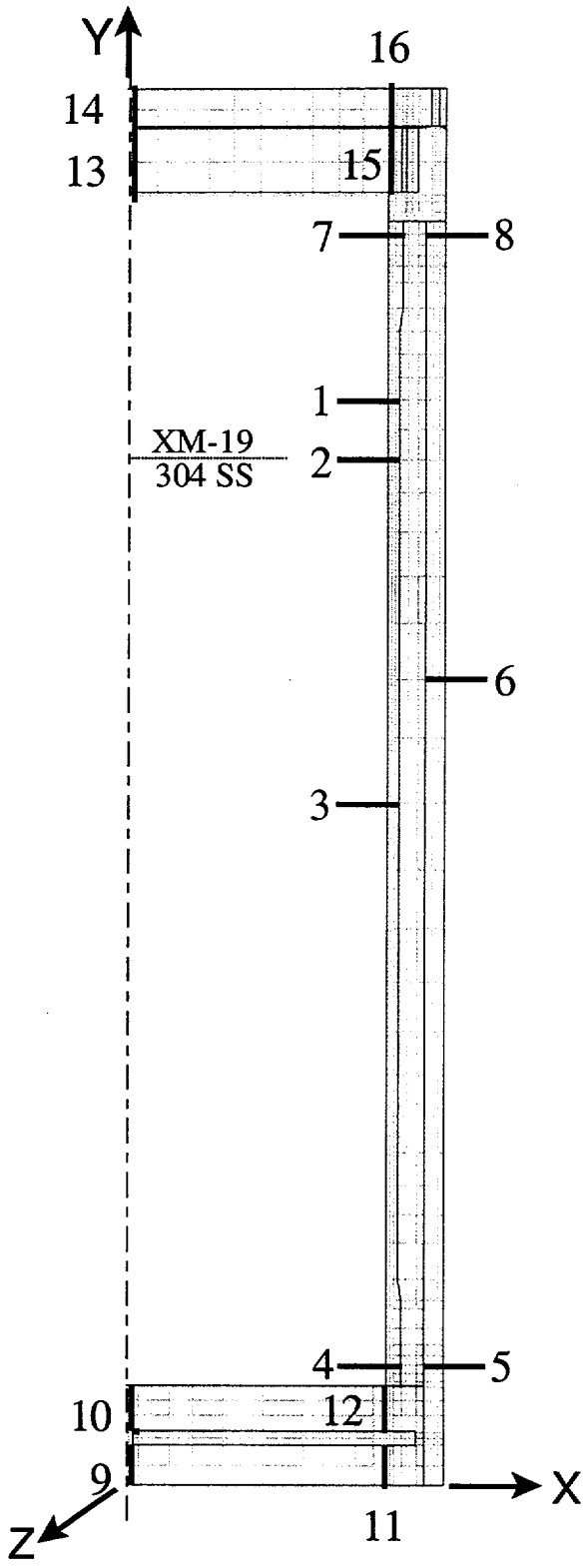


Table 2.7.1.1-1 NAC-STC Section Locations for CY-MPC Stress Evaluation (Maximums)

Section No.	Component Name and Material	Section Location (in.)							
		Inside Node	X	Y	Z	Outside Node	X	Y	Z
1	Transition Shell – XM-19	197	35.5	146.1	0.0	165	37	146.1	0.0
2*	Inner Shell – 304	196	35.5	142.0	0.0	164	37	142.0	0.0
3	Inner Shell – 304	189	35.5	94.2	0.0	157	37	94.2	0.0
4	Bottom Forging – 304	130	35.5	14.5	0.0	123	38	14.5	0.0
5	Outer Shell – 304	280	40.7	14.5	0.0	328	43	14.5	0.0
6	Outer Shell – 304	300	40.7	103.2	0.0	358	43	103.2	0.0
7	Top Forging – 304	271	35.5	173.2	0.0	265	37.5	173.2	0.0
8	Top Forging – 304	317	40.7	173.2	0.0	435	43.4	173.2	0.0
9	Bottom Plate – 304	23	3.16	0.0	0.0	34	3.16	5.45	0.0
10	Bottom Forging – 304	53	3.16	7.45	0.0	65	3.16	13.65	0.0
11	Bottom Plate – 304	22	35.5	0.0	0.0	32	35.5	5.45	0.0
12	Bottom Forging – 304	52	35.5	7.45	0.0	62	35.5	13.65	0.0
13	Inner Lid – 304	486	3.52	178.68	0.0	787	3.52	187.65	0.0
14	Outer Lid – 17-4	514	3.52	187.68	0.0	500	3.52	192.96	0.0
15	Inner Lid – 304	485	35.5	178.68	0.0	796	35.5	187.65	0.0
16	Outer Lid – 17-4	497	35.5	187.68	0.0	495	35.5	192.96	0.0

* This section is at the boundary of transition shell and inner shell.

Table 2.7.1.1-2 NAC-STC Critical P_m Stress Summary for CY-MPC; 30-ft Top End Drop

Section No.	P_m Stresses (ksi)						Stress Intensity Impact (ksi)	Stress Intensity Bolt Preload + Pressure** (ksi)	Stress Intensity Total (ksi)	Allowable Stress* (ksi)	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}					
1	0.0	-4.4	0.0	0.0	0.0	0.0	4.4	1.9	6.3	65.2	9.3
2	0.0	-4.3	0.0	0.0	0.0	0.0	1.6	1.9	3.5	45.9	12.1
3	0.0	-3.5	0.0	0.0	0.0	0.0	3.5	1.9	5.4	45.9	7.5
4	-0.1	-1.5	0.5	-0.2	0.0	0.0	2.0	1.9	3.9	45.9	10.8
5	0.0	-0.6	0.4	0.0	0.0	0.0	1.1	1.9	3.0	45.9	14.3
6	0.0	-3.5	0.8	0.0	0.0	0.1	4.3	1.9	6.2	45.9	6.4
7	-0.5	-3.6	-0.5	0.1	0.0	-0.1	3.2	1.9	5.1	45.9	8.0
8	-0.3	-5.7	-0.1	-0.5	0.1	0.1	5.6	1.9	7.5	45.9	5.1
9	-0.5	0.0	-0.5	0.0	0.0	0.0	0.5	1.9	2.4	45.9	18.1
10	0.4	0.0	0.4	0.0	0.0	0.0	0.5	1.9	2.4	45.9	18.1
11	-0.5	0.0	-0.5	-0.2	0.0	0.0	0.6	1.9	2.5	45.9	17.4
12	0.4	-0.8	0.2	-0.3	0.0	0.0	1.3	1.9	3.2	45.9	13.3
13	-0.4	-2.8	0.1	1.0	-0.2	0.0	3.3	1.9	5.2	45.9	7.8
14	-1.0	-4.4	0.6	0.5	0.0	0.1	5.1	1.9	7.0	45.9	5.6
15	0.0	-2.9	-0.3	0.0	-0.3	0.0	3.0	1.9	4.9	45.9	8.4
16	-0.1	-3.9	0.0	-0.6	-0.3	0.0	4.1	1.9	6.0	45.9	6.7

* Allowable at 331°F (maximum temperature for inner shell) governed by 0.7Su.

** Based on internal pressure of 50 psi.

Table 2.7.1.1-3 NAC-STC Critical $P_m + P_b$ Stress Summary for CY-MPC; 30-ft Top End Drop

Section No.	P_m Stresses (ksi)						Stress Intensity Impact (ksi)	Stress Intensity Bolt Preload + Pressure** (ksi)	Stress Intensity Total (ksi)	Allowable Stress* (ksi)	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}					
1	0.0	-4.6	0.0	0.0	0.0	0.0	4.6	1.9	6.5	93.2	13.3
2	0.0	-4.4	0.0	0.0	0.0	0.0	4.4	1.9	6.3	65.6	9.4
3	0.0	-3.5	0.0	0.0	0.0	0.0	1.2	1.9	3.1	65.6	20.2
4	0.0	-3.6	-0.1	-0.4	0.0	0.0	3.7	1.9	5.6	65.6	11.7
5	0.0	-2.1	0.0	-0.2	0.0	0.0	2.2	1.9	4.1	65.6	15.0
6	0.0	-3.5	0.8	0.0	0.0	0.1	4.4	1.9	6.3	65.6	9.4
7	-0.8	-6.1	-1.5	0.1	0.0	-0.2	5.3	1.9	7.2	65.6	8.1
8	0.1	-9.4	-1.0	-0.3	0.1	0.0	9.5	1.9	11.4	65.6	4.8
9	-2.7	0.0	-2.9	0.0	0.0	0.0	2.8	1.9	4.7	65.6	13.0
10	3.1	0.0	3.4	0.0	0.0	0.0	3.4	1.9	5.3	65.6	11.4
11	-1.8	0.0	-0.3	-0.2	0.0	0.1	1.8	1.9	3.7	65.6	16.7
12	2.4	0.3	0.5	-0.1	0.0	-0.1	2.1	1.9	4.0	65.6	15.4
13	8.1	-0.4	8.8	0.3	0.0	0.0	9.3	1.9	11.2	65.6	4.9
14	1.3	-4.0	3.3	-1.0	0.5	0.1	7.5	1.9	9.4	65.6	6.0
15	-0.1	-2.9	2.0	0.6	-0.1	0.0	4.9	1.9	6.8	65.6	8.7
16	5.6	-3.6	4.5	0.0	-0.2	-0.4	9.4	1.9	11.3	65.6	4.8

* Allowable at 331°F (maximum temperature for inner shell) governed by 0.7Su.

** Based on internal pressure of 50 psi.

Table 2.7.1.1-4 NAC-STC Critical P_m Stress Summary for CY-MPC; 30-ft Bottom End Drop

Section No.	P_m Stresses (ksi)						Stress Intensity Impact (ksi)	Stress Intensity Bolt Preload + Pressure** (ksi)	Stress Intensity Total (ksi)	Allowable Stress* (ksi)	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}					
1	0.0	-3.3	0.0	0.0	0.0	0.0	3.3	1.9	5.2	65.2	11.5
2	0.0	-3.4	0.0	0.0	0.0	0.0	3.4	1.9	5.3	45.9	7.7
3	0.0	-4.2	0.0	0.0	0.0	0.0	4.2	1.9	6.1	45.9	6.5
4	-0.6	-4.4	-1.1	-0.3	0.0	-0.1	3.8	1.9	5.7	45.9	7.1
5	0.0	-7.0	-0.8	0.8	0.0	0.0	7.2	1.9	9.1	45.9	4.0
6	0.0	-4.0	0.6	0.0	0.0	0.1	4.6	1.9	6.5	45.9	6.1
7	-0.1	-2.1	1.1	0.2	0.0	0.1	3.2	1.9	5.1	45.9	8.0
8	0.0	-1.6	1.1	-0.1	0.0	0.1	2.7	1.9	4.6	45.9	9.0
9	-1.6	-5.5	-0.5	-1.8	0.2	0.1	5.8	1.9	7.7	45.9	5.0
10	0.7	-2.9	0.9	-0.7	0.1	0.0	4.0	1.9	5.9	45.9	6.8
11	-0.8	-5.2	-1.1	-0.1	0.8	0.0	4.6	1.9	6.5	45.9	6.1
12	1.0	-2.0	1.1	0.2	0.0	0.0	3.1	1.9	5.0	45.9	8.2
13	-0.3	-0.2	-0.2	0.2	0.0	0.0	0.3	1.9	2.2	45.9	19.8
14	-0.2	-0.4	0.0	0.1	0.0	0.0	0.4	1.9	3.3	45.9	12.9
15	-0.3	-0.8	-0.4	0.5	0.0	0.0	1.1	1.9	3.0	45.9	14.3
16	-0.1	-0.3	-0.1	0.1	0.0	0.0	0.3	1.9	2.2	45.9	19.9

* Allowable at 331°F (maximum temperature for inner shell) governed by 0.7Su.

** Based on internal pressure of 50 psi.

Table 2.7.1.1-5 NAC-STC Critical $P_m + P_b$ Stress Summary for CY-MPC; 30-ft Bottom End Drop

Section No.	P_m Stresses (ksi)						Stress Intensity Impact (ksi)	Stress Intensity Bolt Preload + Pressure** (ksi)	Stress Intensity Total (ksi)	Allowable Stress* (ksi)	Margin of Safety
	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}					
1	0.0	-3.5	-0.1	0.0	0.0	0.0	3.5	1.9	5.4	93.2	16.3
2	0.0	-3.5	0.0	0.0	0.0	0.0	3.5	1.9	5.4	65.6	11.1
3	0.0	-4.3	0.0	0.0	0.0	0.0	4.3	1.9	6.2	65.6	9.6
4	-1.1	-7.3	-2.2	-0.3	0.0	-0.3	6.3	1.9	8.2	65.6	7.0
5	0.2	-12.9	-2.3	0.3	0.0	-0.1	13.1	1.9	15.0	65.6	3.4
6	0.0	-4.0	0.6	0.0	0.0	0.1	4.6	1.9	6.5	65.6	9.1
7	0.0	-2.9	0.9	0.1	0.0	0.1	3.8	1.9	5.7	65.6	10.5
8	0.0	-3.6	0.6	0.3	0.0	0.1	4.2	1.9	6.1	65.6	10.8
9	3.7	-3.5	5.9	-1.2	-0.2	0.1	9.7	1.9	11.6	65.6	4.7
10	9.3	-1.2	10.7	-0.1	0.0	0.1	11.9	1.9	13.9	65.6	3.7
11	4.1	-3.6	4.0	-0.8	0.6	-0.2	8.1	1.9	10.0	65.6	5.6
12	3.6	-1.7	2.5	0.5	0.1	-0.1	5.4	1.9	7.3	65.6	8.0
13	4.7	0.3	5.0	0.1	0.0	0.0	4.7	1.9	6.6	65.6	8.9
14	2.6	-0.2	2.9	-0.1	0.0	0.0	3.2	1.9	5.1	65.6	11.9
15	-0.6	-1.0	1.5	0.7	0.0	0.1	3.0	1.9	4.9	65.6	12.4
16	-0.1	-0.3	1.0	0.2	0.0	0.0	1.4	1.9	3.3	65.6	18.9

* Allowable at 331°F (maximum temperature for inner shell) governed by 0.7Su.

** Based on internal pressure of 50 psi.

THIS PAGE INTENTIONALLY LEFT BLANK

2.7.1.2 Thirty-Foot Side Drop

The NAC-STC is structurally evaluated for the hypothetical accident 30-foot side drop condition in accordance with the requirements of 10 CFR 71.73(c)(1). In this event the NAC-STC, equipped with an impact limiter over each end, falls through a distance of 30 feet onto a flat, unyielding, horizontal surface. The cask strikes the surface in a horizontal position; consequently, a side impact on the cask occurs. The types of loading involved in a side drop accident are closure lid bolt preload, internal pressure, thermal, impact load, and inertial body load. There are three credible side impact conditions to be considered, according to Regulatory Guide 7.8:

1. Side drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

2. Side drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.

3. Side drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

The finite element analysis method is utilized to perform the side drop stress evaluations for the NAC-STC. The side drop accident condition is analyzed using a three-dimensional structural model to accurately represent the non-axisymmetric loads involved in the side drop case. One-half of the cask is modeled as a three-dimensional structure with one plane of symmetry. The ANSYS STIF45 3-D solid element is the primary element type used in the model. In order to reduce the overall problem size, two three-dimensional models have been constructed for the directly loaded fuel configuration--the top fine mesh model and the bottom fine mesh model. A detailed description of the three-dimensional finite element models of the NAC-STC is presented in Section 2.10.2.1.2. The top model contains a fine mesh region at the upper half of the cask with a relatively coarse mesh at the bottom end; the bottom model contains a fine mesh region at the bottom end with relatively coarse mesh at the top end.

Both models are used in the side drop analyses to obtain the detailed stresses throughout the cask for the directly loaded fuel configuration. The stress results from the fine mesh portion of each model are then used to form the final stress summary. For the Yankee-MPC and CY-MPC canistered fuel configurations, the stress results are obtained from the single finite element model of that configuration.

2.7.1.2.1 Thirty-Foot Side Drop—NAC STC and Yankee-MPC Configurations

During a side impact event, the cask body experiences a lateral deceleration. Considering the cask as a free body, the impact limiters apply the load to the side of the cask (in the impact limiter contact area) to produce the deceleration. Since the deceleration represents an amplification factor for the inertial loading of the cask, the equivalent static method is adopted to do the impact evaluations. The analyses consider the behavior of the cask to be linearly elastic. Additionally, fabrication stresses are considered to be negligible (Section 2.6.11).

Five categories of load--closure lid bolt preload, internal pressure, thermal, impact, and body inertia—are considered on the cask:

1. Closure lid bolt preload - The required bolt preload on the inner lid bolts is 115,066 pounds/bolt. For the outer lid bolts, the bolt preload is 36,810 pounds/bolt. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. Pressures of 50 psig and 12 psig are applied on the interior surfaces of the cask cavity for the hot ambient and cold ambient cases, respectively. These pressures envelope the calculated pressures for all cask configurations—directly loaded fuel (12 psig), Yankee-MPC canistered fuel (11.3 psig), and Yankee-MPC canistered GTCC waste (< 11.3 psig).

3. Thermal - The heat transfer analyses determine the cask temperature distributions for the following three combinations of ambient temperature, heat load, and solar insolation for directly loaded fuel:

   Condition 1. 100°F ambient temperature, with maximum decay heat load, and maximum solar insolation.

   Condition 2. -20°F ambient temperature, with maximum decay heat load, and no solar insolation.

2.7.1.3 Thirty-Foot Corner Drop

The NAC-STC in the directly loaded fuel configuration is structurally evaluated for the hypothetical accident 30-foot corner drop condition in accordance with the requirements of 10 CFR 71.73(c)(1). In this event the NAC-STC, equipped with an impact limiter over each end, falls through a distance of 30 feet onto a flat, unyielding, horizontal surface. The cask strikes the surface on its top or bottom corner. The cask center of gravity is directly above the initial impact point for the corner drop condition. For the NAC-STC, an angle of 24 degrees from vertical is calculated for the corner drop orientation. The types of loading involved in a corner drop accident are closure lid bolt preload, internal pressure, thermal, impact load, and inertial body load. There are six credible corner impact conditions to be considered, according to Regulatory Guide 7.8.

1. Top corner drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

2. Top corner drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.

3. Top corner drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

4. Bottom corner drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

5. Bottom corner drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.

6. Bottom corner drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

The finite element analysis method is utilized to perform the corner drop stress evaluations for the NAC-STC. The corner drop accident conditions are analyzed using a three-dimensional structural model to accurately represent the non-axisymmetric loads involved in the corner drop case. One-half of the cask is modeled as a three-dimensional structure with one plane of

symmetry. The ANSYS STIF45 3-D solid element type is used in the model. Two finite element models are constructed; a top fine mesh model and a bottom fine mesh model. Each model is a complete representation of the cask, with a fine mesh region at the impacting end and with a relatively coarse mesh at the opposite end. The fine element mesh is modeled at the impacting end of the cask to provide detailed results in that region. The stresses predicted by the coarse element mesh at the non-impacting end of the model are not critical, so less detail is required. The detailed descriptions of the three-dimensional finite element models of the NAC-STC are described in Section 2.10.2.1.2.

Considering the cask as a free body, the impact limiter will apply the load to the cask impacting corner to produce the deceleration. Since the deceleration represents an amplification factor for the inertial loading of the cask, the equivalent static method is adopted to do the impact evaluations. The analyses consider the behavior of the cask to be linear elastic. Additionally, the fabrication stresses are considered to be negligible (Section 2.6.11).

Five categories of load—closure lid bolt preload, internal pressure, thermal, impact, and body inertia--are considered on the cask:

1. Closure lid bolt preload - The required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively (Section 2.6.7.5). Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3. The bolts are modeled as beam (ANSYS STIF4) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. Pressures of 50 psig and 12 psig are applied on the interior surfaces of the cask cavity for the hot ambient and cold ambient cases, respectively. These pressures envelope the calculated pressures for all cask configurations—directly loaded fuel (12 psig), Yankee-MPC canistered fuel (11.3 psig), and Yankee-MPC canistered GTCC waste (< 11.3 psig).

3. Thermal - The heat transfer analyses performed in Sections 3.4.2 and 3.4.3 determine the cask temperature distributions for the following three combinations of ambient temperature, heat load, and solar insolation for directly loaded fuel:

2.7.1.4 Thirty-Foot Oblique Drop

The NAC-STC is structurally evaluated for the hypothetical accident 30-foot oblique drop condition in accordance with the requirements of 10 CFR 71.73. In this event the NAC-STC, equipped with an impact limiter over each end, falls through a distance of 30 feet onto a flat, unyielding, horizontal surface. The cask strikes the surface obliquely on its top or bottom corner. For the NAC-STC, orientation angles of 15 degrees and 75 degrees are evaluated for the oblique drops. These angles are determined to be the most critical oblique drop orientations, as demonstrated in the following discussion. This section presents the 30-foot oblique drop evaluation for the directly loaded fuel configuration and shows that for the NAC-STC Yankee-MPC and CY-MPC configurations, the side drop results bound the oblique drop results.

The types of loading involved in an oblique drop accident are closure lid bolt preload, internal pressure, thermal, impact load, and inertial body load. There are six credible oblique impact conditions to be considered, according to Regulatory Guide 7.8:

1. Top oblique drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

2. Top oblique drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.

3. Top oblique drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

4. Bottom oblique drop with 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

5. Bottom oblique drop with -20°F ambient temperature, maximum decay heat load, and no solar insolation.

6. Bottom oblique drop with -20°F ambient temperature, no decay heat load, and no solar insolation.

The finite element analysis method is utilized to perform the oblique drop stress evaluations for the NAC-STC. The oblique drop accident conditions are analyzed using a three-dimensional structural model to accurately represent the non-axisymmetric loads involved in the oblique drop case. One-half of the cask is modeled, as a three-dimensional structure with one plane of symmetry. The ANSYS STIF45 3-D solid element is the primary element type used in the model. Two finite element models are constructed--a top fine mesh model and a bottom fine mesh model. Each model is a complete representation of the cask with a fine mesh region at the impacting end and with a relatively coarse mesh at the opposite end. The fine element mesh density is modeled at the impacting end of the cask to provide detailed results in that region. The stresses predicted by the coarse element mesh, at the non-impacting end of the model, are not critical, so less detail is required. The detailed description of the three-dimensional finite element models of the NAC-STC are presented in Section 2.10.2.1.2.

During an impact event, the cask body will experience a deceleration in the oblique drop direction. Considering the cask as a free body, the impact limiter will apply the loads to the impacting corner to produce the deceleration. Since the deceleration represents an amplification factor for the inertial loading of the cask, the equivalent static method is adopted to do the impact evaluations. The analyses consider the behavior of the cask to be linear elastic. Additionally, the fabrication stresses are considered to be negligible (Section 2.6.11).

Five categories of load--closure lid bolt preload, internal pressure, thermal, impact, and body inertial--are considered on the cask:

1. Closure lid bolt preload - The required bolt preloads on the inner lid bolts and the outer lid bolts are 115,066 pounds per bolt and 36,810 pounds per bolt, respectively. Bolt preload is applied to the model by imposing initial strains to the bolt shafts, as explained in Section 2.10.2.2.3. The bolts are modeled as beam (ANSYS STIF4) elements.

2. Internal pressure - The cask internal pressure is temperature dependent and is evaluated in Section 3.4.4. Pressures of 50 psig and 12 psig are applied on the interior surfaces of the cask cavity for the hot ambient and cold ambient cases, respectively. These pressures envelope the calculated pressures for all cask configurations—directly loaded fuel (12 psig), Yankee-MPC canistered fuel (11.3 psig), and Yankee-MPC canistered GTCC waste (< 11.3 psig).

The required weld is less than the actual 3/8-inch weld. The support disk has larger cross-sectional area and moment of inertia than the weld and therefore is qualified by comparison to the weld. No further evaluation is required.

2.7.10.2 CY-MPC GTCC Basket Analysis – Accident Conditions

The CY-MPC GTCC basket is evaluated against the requirements of the ASME Code, Section III, Subsection NF (component supports), to ensure that the basket components are structurally adequate for loads imposed during normal conditions of transport (presented in Section 2.6.19.2) and hypothetical accident conditions (presented in this Section).

The GTCC basket is designed to transport up to 24 containers of GTCC waste. The basket (shield shell weldment) is constructed with 1.75-inch thick SA240 Type 304 stainless steel plates that form walls of a cylinder 141.5-inch long with an internal diameter of 60.5 inches and an external diameter of 64 inches. A total of 12 1-1/4 inch (thickness) × 2.4 inch (width) × 141.5 inch (length) plate/bar, also of Type 304 stainless steel material, is welded along the external surface of the shield shell wall. They are evenly spaced at 30° intervals and provide support to the basket wall structure. The GTCC waste containers (tube array weldment) are positioned and supported using 24 stainless steel tubes that are located within the welded wall structure.

Each stainless steel tube has an 8.74-inch square inside dimension, a 0.375-inch thick wall, and can hold one waste container. The tubes inside the basket are stacked together with a maximum of 6 tubes in a row and are welded together. The twelve perimeter locations where the tubes come in contact with each other are reinforced by plates and angles that are welded over the seams. The plates are connected to the tubes by ¼-inch fillet welds. The tube array rests inside of the basket wall supported by the tube corners in contact with the shell when in a horizontal position. The tube array is prevented from rotation by 3-inch tabs located 27 inches apart in the inside of the shield shell wall. The ends of the basket are enclosed by the canister, which provides end support to tubes in case of non-horizontal configurations.

Tube Array Weldment

The tube array weldment is not required to maintain structural integrity during accident conditions of transport. Therefore, no analysis of the Tube Array Weldment is presented in this section.

Shield Shell Weldment Evaluation

The shield shell weldment is a major component for shielding evaluation and, therefore, is required to maintain structural integrity during accident conditions of transport.

End Drop Analysis

During an end drop the entire weight of the shield shell weldment applies a compressive load at the base of the shell weldment. The shield shell weldment consists of the cylindrical shell and the 12 longitudinal ribs. The weight of the assembly is approximately 15,550 lbs., to account for additional hardware, a total weight of 15,700 lbs. will be used in the evaluation. The impact acceleration is 56.1g.

The cross-sectional area of the shell weldment at the base is:

$$A = \frac{\pi}{4} \times \left[64^2 - 60.5^2\right] = 437.8\,\text{in}^2 \qquad \text{(Area of ribs is neglected)}$$

The stress at the base of the assembly is:

$$S_s = \frac{56.1 \times 15{,}700}{437.8} = 2012\,\text{psi}$$

The maximum temperature at the shield shell is 272°F. Conservatively, using the allowable stresses at 300°F S_m = 20,000 psi, therefore, the margin of safety is:

$$MS = \frac{2.4 \times 20{,}000}{2012} - 1 = +\text{large}$$

Side Drop Analysis

For a side-drop scenario, the same two-dimensional finite element model of the shield shell for the normal condition evaluation is used (see Figure 2.6.19-5). The analysis is performed considering an inertia load of 55 g. Four side drop orientations (45°, 60°, 75° and 90°) are considered. A conservative temperature of 300°F is used to determine the material properties and the allowable stresses.

2.7.13.1.2 Stress Evaluation of CY-MPC Support Disk for a 30-Ft End Drop Condition

Six (6) tie rods locate the support disks of the CY-MPC fuel basket with spacers. A structural analysis is performed using ANSYS to evaluate the effect of a 30-foot end drop impact, which corresponds to the most severe out-of-plane loading under hypothetical accident conditions. The model described in Section 2.7.13.1.1 is used with a 56.1g deceleration. Linearized stresses at the cross sections identified in Figure 2.6.16.2-5 are compared to stress allowables in accordance with the ASME Code, Section III, Subsection NG. Table 2.7.13.1.2-1 lists the 10 highest $P_m + P_b$ stress intensities, respectively. For an end drop, there are no membrane stresses in the support disk because there is essentially no in-plane loading.

The worst case results for the 30-foot end drop condition are summarized as:

$P_m + P_b$	
Stress Intensity (ksi)	M.S.
101.3	0.26

The margin of safety (M.S.) is calculated as: M.S. = (Stress Allowable/Stress Intensity) –1.

Table 2.7.13.1.2-1 P_m+P_b Stresses for CY-MPC Support Disk—30-Foot End Drop

Section*	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
61	88.00	-17.10	33.40	101.30	127.60	0.26
63	88.70	-17.80	-31.10	100.40	127.60	0.27
3	88.10	-16.90	33.00	101.00	131.10	0.30
1	88.60	-16.50	-31.20	100.20	131.10	0.31
76	-3.80	-52.40	16.10	64.80	127.80	0.97
93	-4.30	-52.30	-15.50	64.60	127.80	0.98
94	-4.20	-51.70	-15.60	64.00	127.60	0.99
111	-0.90	-55.00	14.10	62.60	127.60	1.04
129	-47.00	11.70	-15.20	52.60	127.60	1.43
125	-46.90	11.70	-15.20	52.50	128.80	1.45

* See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

2.7.13.1.3 Stress Evaluation of CY MPC Support Disk for a 30-Ft Side Drop Condition

The structural adequacy of the support disk in the CY-MPC fuel basket for the 30-foot side-drop impact load condition was determined. A quasi-static impact load equal to the weight of the fuel and tubes multiplied by a 55g-amplification factor is applied to the support disk structure. The inertial loading of the support disk is also included via the density input for the 17-4 PH stainless steel. The fuel assembly load is transmitted in direct compression through the tube wall to the web structure of the support disk. A finite element analysis is performed using the three-dimensional support disk side model described in Section 2.7.13.1.1. As discussed in Section 2.7.13.1, four bounding cases of basket orientation (0°, 38°, 63°, and 90°) are considered in the analysis. The material properties are evaluated at a combined worst case thermal condition. This condition is based on the maximum support disk temperature from Thermal Condition 1 and the maximum temperature gradient across the disk from Thermal Condition 2. Linearized stresses at 131 cross-sections (see Figure 2.6.16.2-5) are compared to the stress allowable per the ASME Code, Section III, Subsection NG. The allowable stress is $0.7S_u$ for P_m, and $1.0\ S_u$ for $P_m + P_b$ stresses, respectively.

The stress evaluation results for the 30-foot side-drop condition are summarized in Table 2.7.13.1.3-1. The minimum margin of safety is +0.26, which occurs for the 38° basket drop orientation. Tables 2.7.13.1.3-2 through 2.7.13.1.3-9 list the 30 highest P_m and P_m+P_b stress intensities for each basket orientation considered.

Table 2.7.13.1.3-1 Summary of CY-MPC Support Disk Stresses for 30-Foot Side Drop

P_m		P_m+P_b	
Section	Margin of Safety	Section	Margin of Safety
0° Basket Orientation			
11	1.13	1	1.48
13	1.15	3	1.49
1	1.48	11	1.63
3	1.49	9	1.64
9	1.58	13	1.66
38° Basket Orientation			
73	0.79	1	0.26
1	1.42	2	0.58
6	1.73	13	0.61
7	1.91	26	0.62
13	2.07	11	0.62
63° Basket Orientation			
73	1.05	43	0.62
24	1.60	106	0.72
39	1.61	13	0.72
108	1.76	3	0.72
66	2.02	28	0.72
90° Basket Orientation			
108	0.86	129	1.17
90	0.88	108	1.48
105	1.54	90	1.51
87	1.55	44	1.65
110	1.94	24	1.68

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-2 P_m Stresses for CY-MPC Support Disk 30-Foot Side Drop, 0° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
11	-21.3	-21.0	2.0	42.5	90.6	1.13
13	-21.2	-20.7	-1.9	42.1	90.6	1.15
1	-31.6	-5.4	0.7	37.0	91.7	1.48
3	-31.5	-5.3	-0.7	36.8	91.7	1.49
9	-31.4	-3.8	-0.4	35.2	90.9	1.58
7	-31.2	-2.9	0.0	34.1	90.9	1.66
5	-33.4	0.1	0.0	33.4	91.6	1.74
12	-21.4	-9.6	0.0	31.0	90.7	1.92
27	-18.4	-12.0	0.0	30.4	89.6	1.95
4	-30.5	0.0	-1.1	30.6	91.3	1.98
6	-30.4	0.0	1.1	30.5	91.3	1.99
131	-27.3	11.2	7.6	30.4	91.1	2.00
26	-15.4	-12.9	1.1	28.3	89.6	2.17
28	-15.3	-12.7	-1.1	28.1	89.6	2.18
8	-26.2	14.7	0.0	26.2	90.9	2.47
73	-17.5	-8.3	1.1	26.0	90.6	2.49
66	-17.5	-8.4	-1.2	26.0	90.6	2.49
2	-25.5	-0.9	0.0	26.4	92.4	2.51
17	-25.5	0.0	0.0	25.5	90.1	2.54
16	-24.3	0.0	-0.9	24.3	90.1	2.70
18	-24.2	0.0	0.9	24.3	90.1	2.71
69	-19.4	-3.9	-1.2	23.4	90.7	2.87
70	-19.4	-3.9	1.3	23.4	90.7	2.88
42	-13.8	-8.9	0.0	22.7	89.3	2.94
22	-21.7	11.3	0.0	21.7	89.7	3.13
32	-20.1	0.0	0.0	20.1	89.3	3.43
21	-20.1	13.2	1.0	20.2	89.7	3.44
85	-16.8	-3.2	1.4	20.2	89.6	3.44
84	-16.8	-3.2	-1.4	20.2	89.6	3.44
23	-20.0	13.0	-1.0	20.1	89.7	3.45

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-3 P_m Stresses for CY-MPC Support Disk 30-Foot Side Drop, 38° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
73	-50.3	2.8	3.8	50.6	90.6	0.79
1	-19.1	-18.8	-0.5	38.0	91.7	1.42
6	-32.9	0.4	-3.9	33.5	91.3	1.73
7	-17.8	-13.3	1.3	31.2	90.9	1.91
13	-23.5	-5.9	1.1	29.5	90.6	2.07
24	-12.7	28.1	3.8	29.0	89.6	2.09
39	-7.0	27.2	4.4	28.1	89.3	2.17
114	-25.6	-1.6	1.2	27.3	89.3	2.27
121	22.7	3.5	3.9	27.3	89.3	2.27
5	-25.8	0.3	-4.9	27.4	91.6	2.35
38	-13.2	23.3	6.6	26.6	89.3	2.36
23	-19.3	21.6	5.9	26.4	89.7	2.39
88	-23.8	9.2	6.5	26.3	89.6	2.41
103	-20.4	8.9	9.4	25.7	89.3	2.47
66	24.8	-2.7	1.7	24.9	90.6	2.63
14	-13.1	-11.5	1.6	24.8	90.4	2.64
64	-14.7	-9.1	3.4	24.8	90.4	2.65
18	-23.7	0.3	-3.2	24.2	90.1	2.72
106	-18.8	12.6	7.1	23.5	89.3	2.81
91	-20.5	12.2	5.8	23.4	89.6	2.82
3	-23.4	11.9	-1.3	23.5	91.7	2.90
70	-20.3	0.3	5.0	22.3	90.7	3.06
9	-21.9	9.5	2.2	22.3	90.9	3.07
109	-15.0	15.6	6.6	21.9	89.3	3.07
108	4.8	13.8	4.3	20.5	89.3	3.35
2	-19.4	-1.5	-1.4	21.1	92.4	3.38
55	7.1	13.2	0.9	20.4	89.3	3.38
12	-15.3	-5.3	0.4	20.6	90.7	3.39
17	-18.1	0.3	-5.0	20.5	90.1	3.40
8	-20.1	14.0	1.6	20.5	90.9	3.44

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-4 P_m Stresses for CY-MPC Support Disk 30-Foot Side Drop, 63° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
73	-43.8	10.0	3.4	44.1	90.6	1.05
24	-7.6	33.8	4.1	34.5	89.6	1.60
39	-3.2	33.4	4.8	34.2	89.3	1.61
108	11.4	19.8	4.4	32.4	89.3	1.76
66	28.8	1.0	1.8	30.0	90.6	2.02
121	20.6	8.0	3.0	29.2	89.3	2.06
54	1.5	26.0	3.2	28.3	89.3	2.16
90	8.9	17.1	2.9	26.7	89.6	2.36
109	-16.5	22.3	6.1	26.2	89.3	2.41
110	-0.3	25.6	-1.7	25.7	89.3	2.48
106	-19.5	18.0	6.4	25.2	89.3	2.54
91	-20.8	19.6	5.0	25.2	89.6	2.55
38	-8.0	22.2	6.9	25.0	89.3	2.57
88	-21.6	15.4	5.7	24.9	89.6	2.60
75	7.7	17.3	0.4	25.0	90.4	2.62
103	-17.8	13.0	8.4	24.1	89.3	2.70
102	10.2	9.3	7.1	24.1	89.3	2.71
23	-11.7	20.9	6.1	23.9	89.7	2.75
105	6.5	15.2	4.3	23.4	89.3	2.82
1	-8.3	-15.2	-1.1	23.6	91.7	2.88
92	-0.3	22.8	-0.9	22.8	89.5	2.92
111	-9.4	22.4	-0.4	22.4	89.3	2.99
6	-21.4	0.5	-4.1	22.5	91.3	3.06
114	-20.2	-1.1	1.6	21.5	89.3	3.15
107	-0.2	20.9	-2.6	21.3	89.3	3.19
55	7.8	12.8	0.5	20.6	89.3	3.33
129	-8.3	18.7	-3.9	20.0	89.3	3.46
130	-15.5	7.1	7.6	20.0	90.1	3.51
99	11.8	5.2	5.0	19.8	89.3	3.52
64	-15.0	-4.0	3.0	19.9	90.4	3.55

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-5 P_m Stresses for CY-MPC Support Disk 30-Foot Side Drop, 90° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
108	24.0	23.9	0.9	48.0	89.3	0.86
90	23.8	23.9	-0.9	47.7	89.6	0.88
105	16.5	18.7	0.6	35.2	89.3	1.54
87	16.5	18.7	-0.6	35.2	89.6	1.55
110	-0.1	30.4	-0.3	30.4	89.3	1.94
92	-0.1	30.4	0.3	30.4	89.5	1.95
39	9.2	20.6	2.6	30.3	89.3	1.95
29	9.3	20.6	-2.5	30.3	89.6	1.95
44	9.2	19.5	-1.6	28.9	89.3	2.09
14	9.8	19.2	-1.5	29.1	90.4	2.10
24	9.2	19.4	1.6	28.8	89.6	2.11
129	-20.0	20.3	-8.5	28.7	89.3	2.11
54	8.2	19.9	1.1	28.2	89.3	2.17
109	-10.8	26.8	0.9	26.8	89.3	2.33
102	13.9	12.8	0.9	26.8	89.3	2.34
91	-10.6	26.8	-0.9	26.8	89.6	2.34
84	13.8	12.8	-0.8	26.7	89.6	2.35
107	0.0	25.0	-0.3	25.0	89.3	2.57
89	0.0	25.0	0.3	25.0	89.6	2.58
130	-16.0	20.7	5.8	24.6	90.1	2.66
111	-13.1	23.7	-0.5	23.7	89.3	2.76
93	-12.5	23.7	0.6	23.8	89.5	2.76
75	4.9	17.9	0.9	22.9	90.4	2.94
99	13.9	8.3	0.6	22.2	89.3	3.03
81	13.9	8.3	-0.5	22.2	89.6	3.04
123	4.0	17.9	-0.3	22.0	89.3	3.06
106	-14.8	21.8	0.6	21.9	89.3	3.09
88	-14.8	21.8	-0.6	21.9	89.6	3.10
104	0.0	19.5	-0.4	19.6	89.3	3.57
86	0.0	19.6	0.4	19.6	89.7	3.58

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-6 $P_m + P_b$ Stresses for CY-MPC Support Disk 30-Foot Side Drop, 0° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	-52.9	1.6	-0.2	52.9	131.1	1.48
3	-52.6	1.4	0.2	52.6	131.1	1.49
11	-35.1	-13.7	3.1	49.2	129.4	1.63
9	-49.2	0.0	-0.2	49.2	129.8	1.64
13	-34.7	-13.6	-3.0	48.7	129.4	1.66
7	-48.6	2.2	0.0	48.6	129.8	1.67
66	-37.7	15.4	-5.3	38.9	129.4	2.33
131	-34.6	14.7	10.3	38.9	130.2	2.35
73	-37.5	14.9	5.1	38.6	129.4	2.35
81	-33.8	19.0	-3.9	34.7	128.0	2.69
21	-33.0	21.8	-4.6	34.7	128.1	2.69
23	-32.7	21.5	4.6	34.4	128.1	2.73
88	-33.4	18.7	3.9	34.4	128.0	2.73
67	-24.4	-9.7	1.1	34.2	129.5	2.78
72	-24.1	-9.9	-1.1	34.1	129.5	2.79
5	-33.5	0.1	0.0	33.5	130.9	2.91
124	-22.2	15.2	-13.8	33.0	130.3	2.95
70	-14.8	-16.6	-3.8	32.3	129.6	3.01
69	-14.7	-16.6	3.8	32.2	129.6	3.02
4	-32.1	0.0	-1.1	32.2	130.4	3.05
6	-32.0	0.0	1.1	32.1	130.4	3.06
12	-21.5	-9.6	-2.2	31.4	129.6	3.13
27	-18.5	-12.0	0.1	30.4	128.1	3.21
82	-18.2	-12.0	0.3	30.3	128.0	3.23
26	-24.6	-5.4	1.6	30.3	128.0	3.23
28	-24.3	-5.5	-1.6	30.0	128.0	3.27
87	-18.0	-12.0	-0.3	30.0	128.0	3.27
8	-26.3	14.8	-6.6	29.3	129.9	3.43
85	-11.2	-16.1	-1.2	27.3	128.1	3.69
84	-11.0	-16.1	1.3	27.3	128.1	3.69

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-7 $P_m + P_b$ Stresses for CY-MPC Support Disk 30-Foot Side Drop, 38° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	-103.6	4.4	7.0	104.1	131.1	0.26
2	-83.7	14.5	-2.8	83.8	132.1	0.58
13	-80.5	20.4	1.5	80.5	129.4	0.61
26	-78.2	49.7	5.1	79.1	128.0	0.62
11	-79.5	24.3	3.4	79.7	129.4	0.62
41	-77.3	51.8	5.5	78.4	127.6	0.63
3	-78.7	25.4	-9.7	80.4	131.1	0.63
7	-78.7	6.2	7.0	79.4	129.8	0.63
28	-77.9	38.3	2.9	78.1	128.0	0.64
43	-77.2	44.6	4.1	77.7	127.6	0.64
12	-78.1	19.7	-1.2	78.2	129.6	0.66
100	-76.3	38.2	4.2	76.8	127.6	0.66
82	-76.5	36.1	3.8	76.9	128.0	0.67
99	75.9	-38.2	4.1	76.4	127.6	0.67
42	-73.3	58.9	1.9	73.6	127.6	0.73
106	-71.7	30.2	1.8	71.8	127.6	0.78
81	71.1	-38.6	4.9	71.8	128.0	0.78
52	-70.6	30.6	-1.1	70.7	127.6	0.81
88	-70.5	23.2	0.4	70.5	128.0	0.82
103	-68.0	47.2	4.4	68.9	127.6	0.85
70	-68.0	3.2	0.1	68.0	129.6	0.91
105	-66.0	57.6	2.8	66.8	127.6	0.91
66	67.6	-35.8	-1.3	67.6	129.4	0.91
67	-67.5	13.7	2.5	67.6	129.5	0.91
73	-66.8	5.6	-6.7	67.6	129.4	0.92
102	-54.1	62.1	7.3	66.4	127.6	0.92
84	-63.0	59.0	4.5	65.9	128.1	0.94
51	-63.8	36.6	4.5	64.5	127.6	0.98
69	-65.0	22.3	-0.3	65.0	129.6	0.99
37	-47.8	63.7	1.9	64.0	127.6	0.99

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-8 $P_m + P_b$ Stresses for CY-MPC Support Disk 30-Foot Side Drop, 63° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
43	-78.7	54.6	2.6	79.0	127.6	0.62
106	-74.3	40.8	0.3	74.3	127.6	0.72
13	-75.3	31.2	0.6	75.3	129.4	0.72
3	-74.1	30.5	-9.7	76.2	131.1	0.72
28	-74.1	47.2	1.7	74.2	128.0	0.72
41	73.3	-41.5	4.4	73.9	127.6	0.73
1	-74.6	3.3	5.7	75.0	131.1	0.75
99	71.3	-25.7	2.6	71.4	127.6	0.79
129	-40.3	47.9	-26.6	70.9	127.6	0.80
100	-70.4	41.5	2.2	70.6	127.6	0.81
2	-71.6	18.8	-2.6	71.7	132.1	0.84
105	68.9	-26.0	4.0	69.3	127.6	0.84
88	-68.7	33.8	-0.6	68.7	128.0	0.86
42	-67.2	63.4	0.8	67.4	127.6	0.89
26	-66.9	50.1	3.0	67.4	128.0	0.90
82	-65.9	38.6	1.8	66.0	128.0	0.94
73	-65.3	18.8	-6.7	66.2	129.4	0.95
81	65.2	-23.6	2.7	65.4	128.0	0.96
11	65.5	-33.5	3.6	65.9	129.4	0.96
103	-63.8	52.8	3.3	64.7	127.6	0.97
44	-62.8	33.7	1.2	62.8	127.6	1.03
12	-63.4	24.1	-0.8	63.4	129.6	1.04
102	60.5	-39.0	5.7	61.9	127.6	1.06
52	-60.5	23.9	0.8	60.6	127.6	1.11
66	60.9	-20.9	-2.4	61.1	129.4	1.12
108	58.3	-15.6	3.6	58.6	127.6	1.18
40	58.2	-17.2	1.4	58.3	127.6	1.19
87	57.4	-24.3	3.9	57.9	128.0	1.21
25	57.8	-13.7	1.4	57.9	128.0	1.21
37	-33.2	56.8	3.4	57.3	127.6	1.23

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

Table 2.7.13.1.3-9 $P_m + P_b$ Stresses for CY-MPC Support Disk 30-Foot Side Drop, 90° Basket Orientation

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
129	-35.4	38.6	-21.7	58.8	127.6	1.17
108	31.3	20.0	-1.9	51.5	127.6	1.48
90	30.7	20.2	2.0	51.0	128.0	1.51
44	41.4	6.8	-0.9	48.2	127.6	1.65
24	40.6	7.1	0.9	47.7	128.0	1.68
39	27.0	16.2	1.8	43.4	127.6	1.94
29	27.2	16.1	-1.8	43.4	128.0	1.95
105	23.3	14.9	-1.5	38.3	127.6	2.33
130	-25.8	27.8	11.8	38.7	128.8	2.33
87	23.1	15.1	1.5	38.3	128.0	2.35
14	10.4	23.1	-3.4	34.1	129.2	2.79
43	30.7	2.4	0.9	33.2	127.6	2.85
23	30.5	2.6	-0.9	33.1	128.1	2.87
54	8.6	23.0	3.7	32.4	127.6	2.94
110	-0.1	31.8	-0.4	31.8	127.6	3.01
111	-15.7	27.7	-8.1	31.8	127.6	3.01
92	-0.1	31.8	0.3	31.8	127.9	3.03
93	-14.7	27.5	8.4	31.7	127.8	3.04
109	-17.9	29.4	-2.8	30.1	127.6	3.24
91	-17.2	29.1	2.8	29.8	128.0	3.30
38	17.7	11.9	0.2	29.7	127.6	3.30
28	18.0	11.7	-0.2	29.7	128.0	3.30
40	-28.4	14.6	-2.4	28.8	127.6	3.42
106	-21.5	25.4	-4.7	28.5	127.6	3.47
20	-28.2	14.5	2.4	28.6	128.0	3.47
88	-21.3	25.2	4.8	28.4	128.0	3.51
102	8.4	18.2	2.5	27.0	127.6	3.72
84	8.6	18.0	-2.4	27.0	128.1	3.74
41	-25.6	21.3	-2.6	26.8	127.6	3.76
42	-19.8	25.0	-3.1	26.5	127.6	3.82

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

2.7.13.1.4 Stress Evaluation of CY-MPC Support Disk for 30-Ft Oblique Drop

This section documents the methodology used to calculate the stresses associated with oblique impacts of the transport cask (Figure 2.7.13.1-2). The results show that the stress criteria are met for all oblique conditions. Note that the methodology used for the off-angle drop evaluation is very conservative since the g loads decrease significantly for oblique drops (Section 2.6.7.4).

To evaluate oblique impacts, the stress components (i.e., S_x, S_y, S_{xy}) are combined from the side drop and end drop cases for both the 0° the 38° basket drop orientations (Figure 2.7.13.1-1). The stresses are combined according to the following cask drop angles: ϕ = 0°, 24°, 30°, 45°, 60°, 73°, 75°, 77°, 80°, 83°, 85°, 88° and 90°. Note that the 0° and 90° cask drop angles are equivalent to the end- and side- drop cases, respectively. The normal stresses (S_x and S_y) and the shear stress (S_{xy}) for a drop with an angle of ϕ (Figure 2.7.13.1-2) are calculated using the following equations:

$$S_{x(\phi)} = S_{x(end)}\text{Cos}\phi + S_{x(side)}\text{Sin}\phi\,,$$

$$S_{y(\phi)} = S_{y(end)}\text{Cos}\phi + S_{y(side)}\text{Sin}\phi\,,$$

$$S_{xy(\phi)} = S_{xy(end)}\text{Cos}\phi + S_{xy(side)}\text{Sin}\phi\,,$$

where:

$S_{x(end)}$, $S_{y(end)}$, and $S_{xy(end)}$ are the sectional stresses resulting from the Support Disk End Drop Model, and $S_{x(side)}$, $S_{y(side)}$, and $S_{xy(side)}$ are the section stresses resulting from the Support Disk Side Drop Model.

Off-angle principle stresses (i.e., S_1, S_2) are calculated by using the following equation:

$$S_1, S_2 = \frac{S_{x(\phi)} + S_{y(\phi)}}{2} \pm \sqrt{\left(\frac{S_{x(\phi)} - S_{y(\phi)}}{2}\right)^2 + S_{xy(\phi)}^2}$$

Once the principle stresses are calculated, new stress intensities (SI) can be calculated. Summaries of the maximum support-disk stress-intensities in the 30-foot oblique drop conditions are given in Table 2.7.13.1.4-1.

Table 2.7.13.1.4-1 CY-MPC Support Disk Stress Summary for the 30-Foot Oblique Drop

Stress State	Section[2]	Cask Drop Angle (°)[3]	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
0° BASKET DROP ORIENTATION								
P_m	11	90	-21.3	-21.0	2.0	42.5	90.6	1.13
P_m+P_b	61	0	88.0	-17.1	33.4	101.3	127.6	0.26
38° BASKET DROP ORIENTATION								
P_m	73	90	-50.3	2.8	3.8	50.6	90.6	0.79
P_m+P_b	1	30	109.4	-35.3	-30.9	120.6	131.1	0.09

Notes:

1. P_m = Primary Membrane Stress, $P_m + P_b$ = Primary Membrane + Bending Stress.
2. See Figure 2.6.16.2-5 for section locations.
3. See Figure Figure 2.7.13.1-2 for definition of cask drop angle.
4. Allowable Stress for 17-4PH, Type 630 stainless steel:

   For P_m, $S_{allow} = 0.7\ S_u = 89.3$ ksi at 550°F
   $= 94.5$ ksi at -40°F

   For $P_m + P_b$, $S_{allow} = S_u = 127.6$ ksi at 550°F
   $= 135.0$ ksi at -40°F

Buckling evaluations are performed on all sections in the disk ligaments defined in Figure 2.6.16.2-5. Using the cross-sectional stresses calculated at each of the sections for each loading condition the maximum corresponding compressive forces (P) and bending moment are determined as follows,

$$P = \sigma_m A,$$

$$M = \sigma_b A,$$

where, σ_m is the membrane stress, σ_b is the strong axis bending stress or weak axis bending stress, A is the area (b × t), and S is the section modulus ($tb^2/6$ for strong axis bending and $bt^2/6$ for weak axis bending).

To determine the margin of safety:

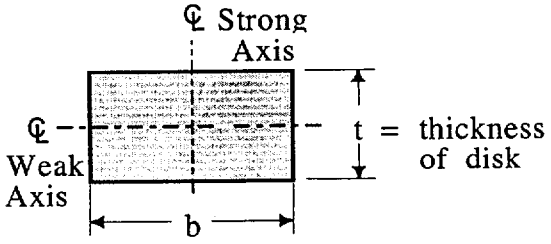
$$P_1 = P/P_{cr} \qquad M_1 = \frac{C_m M}{(1 - P/P_e)M_m} \qquad (P_1 + M_1 \le 1) \quad \text{(Eq. 31, NUREG/CR-6322)}$$

and $$P_2 = P/P_y \qquad M_2 = \frac{M}{1.18\, M_p} \qquad (P_1 + M_1 \le 1) \quad \text{(Eq. 32, NUREG/CR-6322)}$$

The margins of safety are:

$$MS1 = \frac{1}{P_1 + M_1} - 1$$

$$MS2 = \frac{1}{P_2 + M_2} - 1$$



The side drop conditions are the governing conditions for strong axis buckling evaluation since the axial compressive force (P) and the strong axis bending moment (M) decrease with the drop angle. Therefore, evaluation of strong axis buckling is performed for side-drop conditions only.

Buckling analysis was completed only for the 38° basket orientation because this is the worst case angle (See Section 2.7.13.1). The minimum margin of safety is +0.34, which occurs at section number 1. The results for the 20 worst-case sections are summarized in Table 2.7.13.3-1.

Table 2.7.13.3-1 NUREG/CR 6322 Buckling Analysis for CY-MPC Support Disk 30-Foot Side Drop, 38° Basket Orientation

Sect.	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
1	10.44	59.07	49.07	8.49	13.49	13.22	0.35	0.34
13	12.90	58.15	48.30	5.74	13.28	13.02	0.64	0.58
2	14.51	87.24	67.61	12.04	25.36	25.36	0.74	0.62
3	12.81	59.07	49.07	5.57	13.49	13.22	0.70	0.64
7	9.71	58.35	48.47	6.13	13.33	13.07	0.73	0.69
28	8.25	57.25	47.54	6.33	13.07	12.83	0.74	0.71
12	11.43	85.12	65.94	11.76	24.73	24.73	0.84	0.73
43	4.85	56.89	47.23	6.89	12.99	12.75	0.82	0.81
11	2.94	58.14	48.29	7.45	13.28	13.02	0.85	0.86
26	2.88	57.25	47.54	7.33	13.07	12.83	0.85	0.87
42	6.73	83.16	64.40	12.04	24.15	24.15	0.97	0.90
41	0.97	56.89	47.23	7.60	12.99	12.75	0.90	0.94
52	5.52	83.16	64.40	11.85	24.15	24.15	1.06	0.99
8	14.98	85.35	66.13	8.01	24.80	24.80	1.20	1.00
9	12.00	58.35	48.47	3.85	13.33	13.07	1.15	1.03
27	9.43	83.72	64.85	9.24	24.32	24.32	1.28	1.14
111	12.98	83.16	64.40	7.55	24.15	24.15	1.35	1.14
23	10.59	57.31	47.59	3.76	13.09	12.84	1.27	1.15
22	11.39	83.83	64.93	8.32	24.35	24.35	1.32	1.15
21	4.41	57.31	47.59	5.46	13.09	12.84	1.26	1.24

Note: See Figure 2.6.16.2-5 for section locations and definition of coordinate system.

two elements adjacent to a given node. Tables 2.10.2-3 and 2.10.2-4 document the calculated effective properties for all of the bolts in both lids, including the associated real constant numbers. Following are example calculations for the inner and outer lid bolt properties:

Inner Lid Bolts (42, 1 1/2 - 8 UN)

Tensile area of one bolt = 1.492 in^2
Total tensile area = (42)(1.492) = 62.66 in^2
Bolt minor radius (R) = 1.3444/2 = 0.6722 in
Moment of inertia (I) of one bolt = $\pi R^4/4$ = 0.1604 in^4
Total moment of inertia = (42)(0.1604) = 6.7368 in^4

Referring to Table 2.10.2-3, the inner lid bolt properties for circumferential plane location 4, real constant number 17, are:

Tensile area = (0.0522)(62.66)(0.5) = 1.6354 in^2
I = (0.0522)(6.7368)(0.5) = 0.1758 in
Diameter for stress recovery = $[(1.492)(4)/\pi)]^{0.5}$ = 1.378 in

Additionally, to determine the shear area of the bolt, a shear factor of 10/9 is applied to the bolt tensile area, as recommended by the ANSYS User's Manual, Section 4.0.5. In the ANSYS model, bolt head properties are taken to be 10 times the associated bolt shaft properties.

Outer Lid Bolts (36, 1 - 8 UNC)

Tensile area of one bolt = 0.606 in^2
Total tensile area = (36)(0.606) = 21.816 in^2
Bolt minor radius (R) = 0.8446/2 = 0.4223 in
Moment of inertia (I) of one bolt = $\pi R^4/4$ = 0.0250 in^4
Total moment of inertia = (36)(0.0250) = 0.900 in^4

Referring to Table 2.10.2-4, the outer lid bolt properties for circumferential plane location 8, real constant number 38, are:

Tensile area = (0.0639)(21.816)(0.5) = 0.697 in^2
I = (0.0639)(0.900)(0.5) = 0.02876 in
Diameter for stress recovery = $[(0.606)(4)/\pi)]^{0.5}$ = 0.878 in

Additionally, to determine the shear area of the bolt, a shear factor of 10/9 is applied to the bolt tensile area, as recommended by the ANSYS User's Manual, Section 4.0.5. In the ANSYS model, bolt head properties are taken to be 10 times the associated bolt shaft properties.

The bolt preload is calculated as shown in Section 2.6.7.5. The preload on the inner lid bolts is calculated to be 115,066 pounds per bolt. The preload on the outer lid bolts is calculated to be 36,810 pounds per bolt.

Section 2.10.2.2.3 contains a detailed description of the bolt preload strain calculation for both the inner and outer lids.

2.10.2.1.3 Transport Cask Body Finite Element Model for the Canistered Fuel Configurations

The cask body model used for the Yankee-MPC and CY-MPC analyses is represented using ANSYS SOLID45, BEAM4, CONTACT52, and spring/damper COMBIN14 elements. Gap elements are used to model contact interfaces between components. Friction effects are ignored in the model. Lump mass elements (MASS21) are used to model components such as the impact limiters and NS-4-FR gamma shield.

The loaded canister is represented by a surface pressure load as described in Section 2.10.2.2.1. An acceleration of 20g is applied to the cask and canister for the 1-ft drop. The pressure load for the canister lid and canister body loaded with fuel is applied to the cask body using a cosine-shaped pressure distribution, where the total pressure applied to the cask body is equal to the total impact load of the contents. The weight of the spacers is included in the weight of the canister and contents. Gap elements are defined at both ends of the cask to simulate the pressure applied by the impact limiters during drop conditions (based on a cosine distribution). The stiffness of the gap elements is varied from a maximum value (1×10^6 lb/in) at the line of impact to a lower

For the corner and oblique drop analyses, the impact pressure loading is a combination of the end drop impact pressure load and the side drop impact pressure load. The corner and oblique drop impact pressure loadings are determined by breaking up the impact pressure load into longitudinal and lateral components, based on the drop angle. The longitudinal component is applied to the cask end, and the lateral component is applied to the cask inner shell as previously described for the side drop case.

2.10.2.2.3 Bolt Initial Strain Determination

The standard technique for applying bolt preload to a finite element model is employed. The bolts are modeled using beam elements, ANSYS STIF3 elements for the two-dimensional model and ANSYS STIF4 elements for the three-dimensional top fine mesh model. Each bolt is modeled by four beam elements, two that represent the bolt head and two that represent the bolt shaft. The two bolt head elements are defined by three nodes that are an integral part of the non-threaded plate. The bolt head elements are assigned a stiffness of 10 times the actual bolt stiffness. The first bolt shaft element connects the center node of the bolt head with a node located at the top of the threaded hole. This element represents the portion of the bolt that is not engaged in the threaded hole. This portion of the bolt will be in tension due to the bolt preload. The second bolt shaft element connects the node at the top of the threaded hole with a node at the bottom of the threaded hole. This element represents the portion of the bolt that is engaged in the threaded hole. The two bolt shaft elements are assigned material property values (area and stiffness) equal to the actual bolt properties.

The effect of bolt preload is imposed on the model by applying an initial strain to the bolt shaft. The initial strain is applied only to the beam element representing the portion of the bolt shaft not engaged in threads. The initial strain values, which result in the required preload values, are determined by first running ANSYS analyses of both the two-and three-dimensional models with a "trial" initial strain, applied to the bolt shaft element, as the only loading condition. The resulting beam element force (from the element representing the portion of the bolt shaft not engaged in threads), is then used to ratio the trial initial strain to a value that will result in a beam element force closer to the actual bolt preload. This procedure is performed iteratively until the beam element force is effectively equal to the actual bolt preload.

The trial initial strain values are first determined by performing hand calculations of the value of P/nAE for the inner and the outer lid bolts. For the inner lid bolts, the calculation considers a required bolt preload of 115,066 pounds per bolt, a quantity (n) of 42 bolts, a bolt cross-sectional area (A) of 1.492 square inches per bolt, and a Young's modulus (E) of 31.0×10^6 psi.

For the outer lid bolts, the calculation considers a required bolt preload (P) of 36,810 pounds per bolt, a quantity (n) of 36 bolts, a bolt cross-sectional area (A) of 0.606 square inches per bolt, and a Young's modulus (E) of 28.3 x 10^6 psi.

2.10.2.2.4 Contents Pressure Calculation—CY-MPC Configuration

For the end drop analyses, the contents weight is assumed to be uniformly distributed on the cask end, over an area determined by the inside diameter of the cask. Therefore, the conservatively assumed CY-MPC contents weight of 67,621 pounds (Fuel + Fuel Basket + Canister with lids + Spacer = 35,100 + 14,055 + 16,666 + 1,800), and the cask cavity inside radius of 35.5 inches are used to calculate a contact pressure of:

$$p = \frac{67,621}{(\pi)(35.5)^2} = 17.08 \text{ psi}$$

Note a spacer heavier than the weight reported in Table 2.2-4 is conservatively used in this evaluation.

This pressure applies to a 1 g loading condition. Pressure values for the 1-foot and 30-foot end drop analyses are determined by ratioing this pressure by the g-load values applicable to the specific case, which are documented in Sections 2.6.7.1 and 2.7.1.1.

For the side drop condition, the cask contents are conservatively assumed to contact the inner cask diameter on an arc of only 30 degrees during the 1-foot drop and 45 degrees during the 30-foot drop on either side of the impact centerline. The inertial load produced by each component (Lids + Canister body and fuel + Spacer) are represented as equivalent static pressures applied on the interior surface of the cask. The pressures are uniformly distributed along the cavity length, and are varied in the circumferential direction as a cosine distribution. The maximum pressure occurs along the impact centerline and decreases to zero at 30 degrees (1-foot drop) or 45 degrees (30-foot drop) either side of the impact centerline. The method used to determine the varying pressures on the elements within the contact arc is presented in Section 2.10.2.2.1.

2.10.3 LS-DYNA Computer Code

Two separate cases are used to verify the LS-DYNA program as a tool to predict the deceleration of the cask body during normal and accident conditions. LS-DYNA provides two strain rate dependent material models that adequately simulate the behavior of wood crushing during a dynamic impact event. Benchmarking of the two material properties and the method of analysis are presented in the following sections. The first verification problem is designed to determine the accuracy of the modeling methodology when compared to closed form solutions. The second verification problem shows that strain rate dependent material models properly interpolate between inputted stress-strain curves at a given strain rate.

2.10.3.1 Predicting Impact Deceleration using Strain Rate Sensitive Properties

The validation of the use of LS-DYNA to represent the behavior of the balsa impact limiters was accomplished by using the balsa stress strain curve for a simple geometry for which the crushing and acceleration could be determined. The geometry used is shown in Figure 2.10.3.2-1, which corresponds to a right circular cylinder 50 inches in diameter and 50 inches in length. The model employed symmetry boundary conditions for the quarter symmetry model. The stress strain curve representative of balsa material is shown in Figure 2.10.3.2-2. The material model used in this evaluation is the FU_CHANG_FOAM (material 83), which is the material model employed in the balsa impact limiter evaluation. The impacting object is a quarter symmetry circular plate of the same diameter with an assigned weight of 257 kips. The interface between the balsa cylinder and the plate is modeled using automatic surface to surface, while the unyielding surface was modeled using the RIGIDWALL_GEOMETRIC_FLAT option. The system has an initial velocity of 150 in/sec. To compute the crush, an energy balance is used.

$$\frac{mv_o^2}{2} = AL\int_0^{\varepsilon_i} \sigma_i \, d\varepsilon$$

where:

- A = area of the block being crushed
- L = total original height of the block
- $d\varepsilon_i$ = the incremental strain as the block crushes
- σ_i = the stress at the given incremental strain value

The acceleration is computed by σ A/W (g), where W is the weight of the modeled plate. The peak crush strength is 2,090 psi obtained from Figure 2.10.3.2-2. The results of the calculation are:

Item	LS-DYNA	Calculation	% Difference
Crush (in)	12.9	12.6	2
Acceleration (maximum) (g)	4.04	3.99	1

This demonstrates that the material model and numerical methodology employed in LS-DYNA for the balsa impact limiters is acceptable.

2.10.3.2 Accounting for Strain Rate Sensitivity by Interpolation

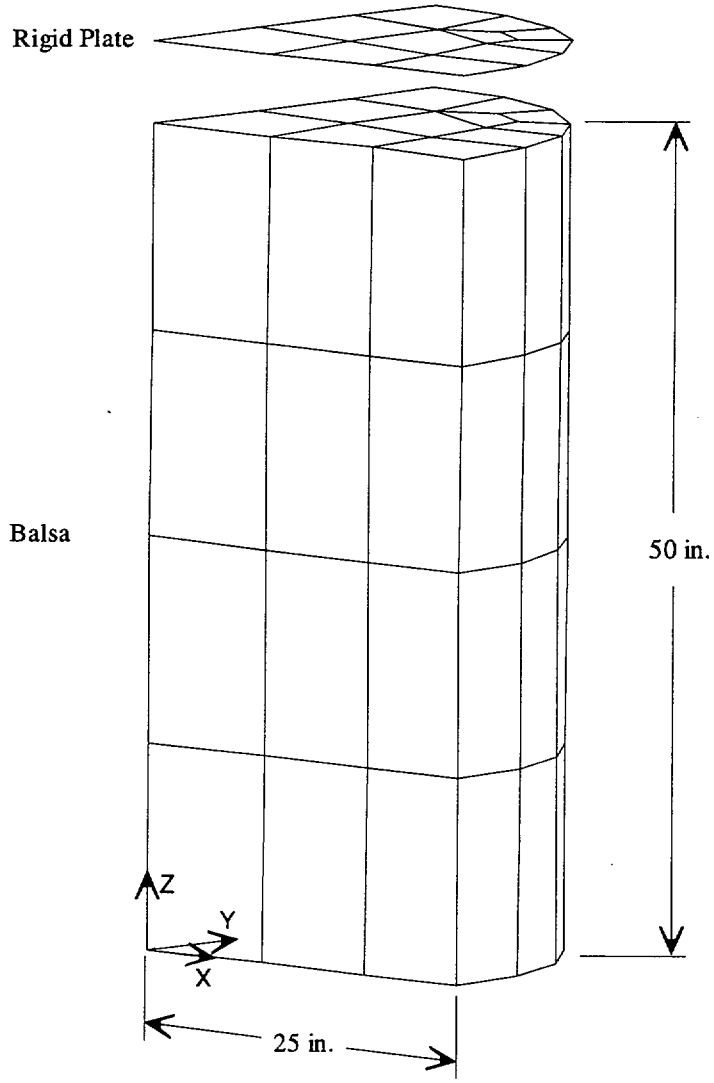
The strain rate sensitive foam/wood is modeled using the LS-DYNA finite element model builder (FEMB). The model is comprised of a steel block and a wooden cube. The model as shown in Figure 2.10.3.2-3 is constructed of solid brick elements. The wooden cube measures 5 inches by 5 inches. The impacting steel plate is 5 inches tall and 7.5 inches across. Surface-to-surface contact interfaces are employed between the steel block and the wooden cube. The wooden cube sits on a rigid plane.

The Piecewise_Linear_Plasticity material model is used to represent the steel block. The wooden cube is represented as a homogeneous isotropic material, type number 163 in LS-DYNA (Modified_Crushable_Foam). For this example, three strain rates are inputted into the material model, 0 ε/sec, 20 ε/sec, 60 ε/sec, with corresponding constant stress values of 2000 psi, 7000 psi and 10,000 psi, respectively. A prescribed motion is applied to the steel block to apply a constant strain rate to the wood cube after 0.01 seconds.

To demonstrate that the correct strain rate curve is used during the crushing of the wood cube two cases are considered. The first case uses 20 ε/sec, and the second case uses 40 ε/sec. The stress in the wood block should compare to the applied stress-strain curve at the strain rate of interest. For the 20 ε/sec case, the compressive stress in the cube is approximately 7,000 psi, which agrees with the LS-DYNA result. For the 40 ε/sec case, the compressive stress in the cube is a value of 8,000 psi, due to logarithmetic interpolation that agrees with the LS-DYNA result in

Figure 2.10.3.2-5. Therefore, the Modified_Crushable_Foam material model is an acceptable method of accounting for the strain rate variability of foam and wood crushable materials.

Figure 2.10.3.2-1 LS-DYNA Model used to Verify the Material Model



Note: XZ and YZ planes are planes of symmetry.

Figure 2.10.3.2-2 Stress-Strain Curve used for the Balsa Material

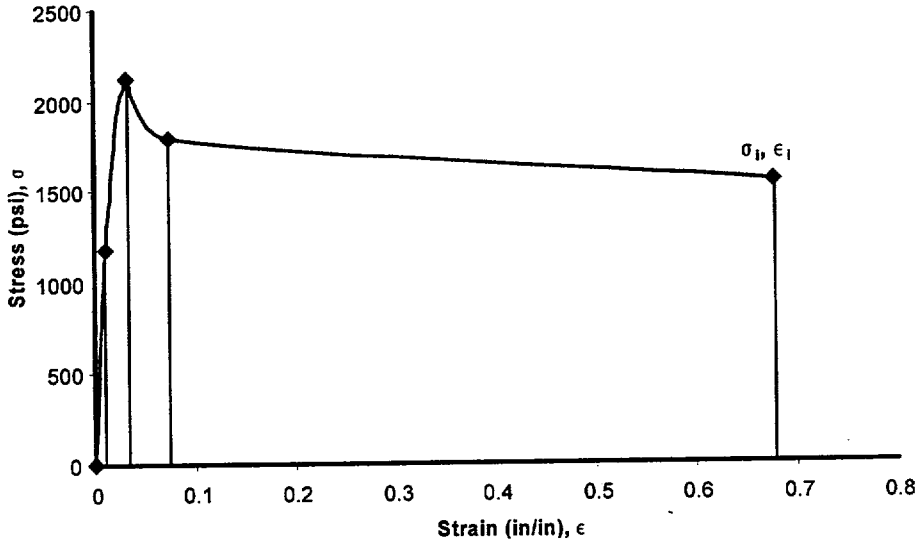


Figure 2.10.3.2-3 Finite Element Model for Strain-Rate Dependent Crushable Foam/Wood Block Impact

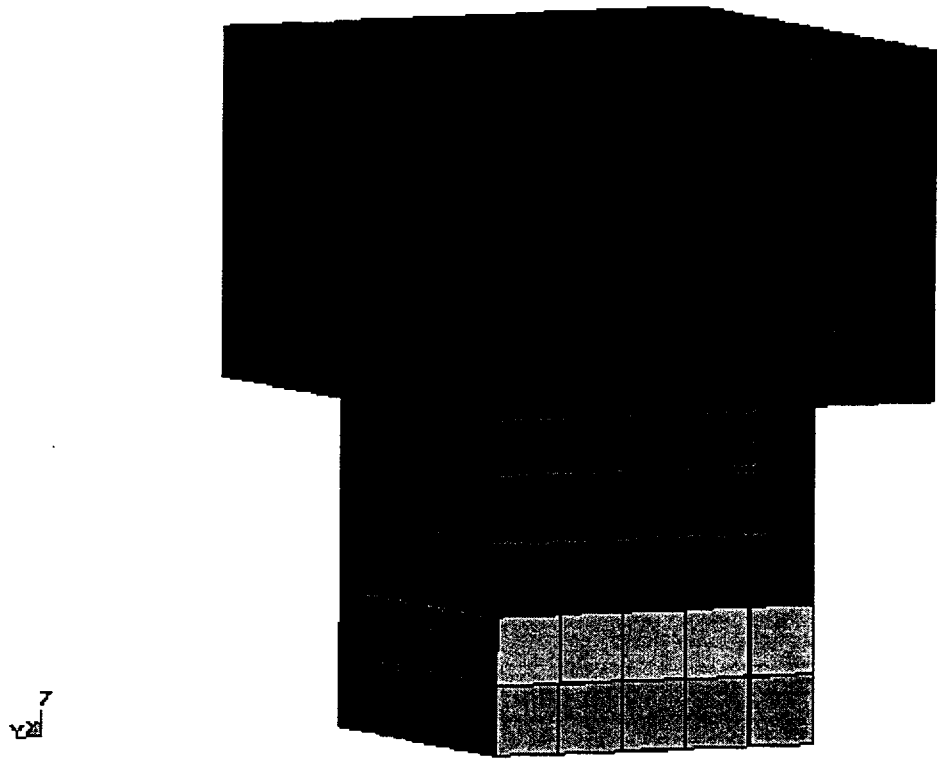


Figure 2.10.3.2-4 Stress Time History at 20 ε/sec

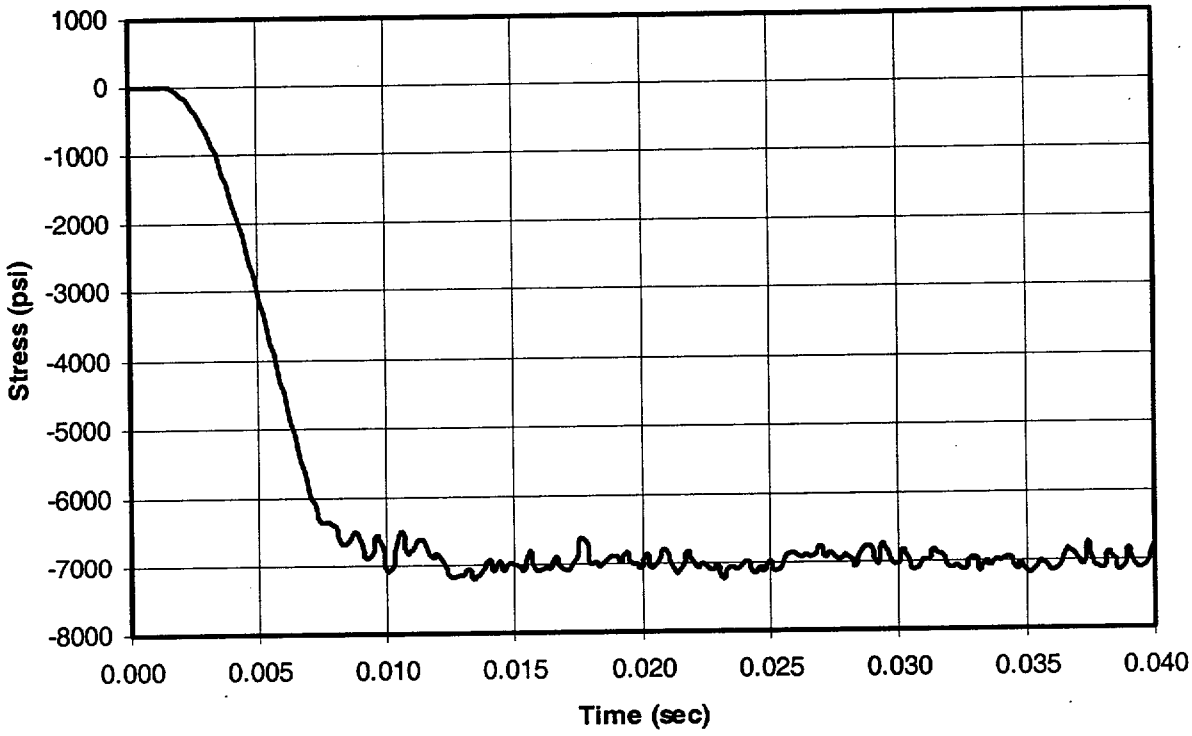
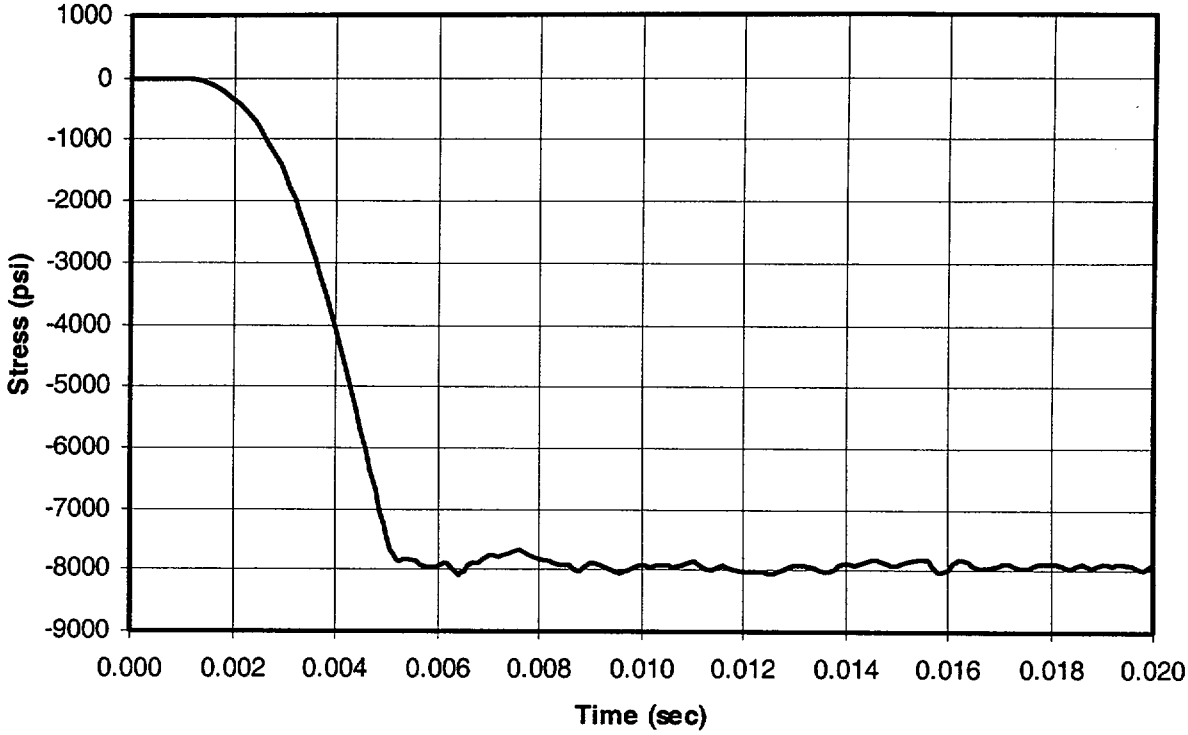


Figure 2.10.3.2-5 Stress Time History at 40 ε/sec



Revision STC-02A

May 2002

NAC-STC

NAC Storable Transport Cask

SAFETY ANALYSIS REPORT

Volume 2 of 2

Amendment for
CONNECTICUT YANKEE ATOMIC POWER COMPANY

NAC INTERNATIONAL

Atlanta Corporate Headquarters
3930 East Jones Bridge Road, Norcross, Georgia 30092
Phone 770-447-1144, Fax 770-447-1797
www.nacintl.com

List of Effective Pages

Master Table of Contents

i .....Revision STC-00A
ii .....Revision STC-00A
iii .....Revision STC-00A
iv .....Revision STC-00A
v.....Revision STC-00A
vi .....Revision STC-00A
vii .....Revision STC-02A
viii .....Revision STC-00A
ix .....Revision STC-00A
x .....Revision STC-00A
xi .....Revision STC-02A
xii .....Revision STC-01B
xiii .....Revision STC-01B
xiv .....Revision STC-01B
xv .....Revision STC-01B
xvi .....Revision STC-01B
xvii .....Revision STC-02A

Chapter 1

1-i .....Revision STC-00A
1-ii .....Revision STC-01B
1-iii .....Revision STC-01B
1-iv .....Revision STC-02A
1-v .....Revision STC-01B
1-1 .....Revision STC-01B
1-2 .....Revision STC-01B
1-3 .....Revision STC-00A
1-4 .....Revision STC-00A
1-5 .....Revision STC-00A
1-6 .....Revision STC-00A
1-7 .....Revision STC-01B
1-8 .....Revision STC-01B
1-9 .....Revision STC-01B
1.1-1 .....Revision STC-00A
1.1-2 .....Revision STC-00A
1.1-3 .....Revision STC-00A
1.1-4 .....Revision STC-00A
1.1-5 .....Revision STC-01B
1.1-6 .....Revision STC-01B
1.2-1 .....Revision STC-00A
1.2-2 .....Revision STC-00A
1.2-3 .....Revision STC-00A
1.2-4 .....Revision STC-00A
1.2-5 .....Revision STC-00A
1.2-6 .....Revision STC-01B
1.2-7 .....Revision STC-00A
1.2-8 .....Revision STC-01B
1.2-9 .....Revision STC-00A
1.2-10 .....Revision STC-00A
1.2-11 .....Revision STC-00A
1.2-12 .....Revision STC-00A
1.2-13 .....Revision STC-00A
1.2-14 .....Revision STC-00A
1.2-15 .....Revision STC-00A
1.2-16 .....Revision STC-00A
1.2-17 .....Revision STC-01B
1.2-18 .....Revision STC-00A
1.2-19 .....Revision STC-00A
1.2-20 .....Revision STC-00A
1.2-21 .....Revision STC-00A
1.2-22 .....Revision STC-00A
1.2-23 .....Revision STC-00A
1.2-24 .....Revision STC-01B
1.2-25 .....Revision STC-00A
1.2-26 .....Revision STC-00A
1.2-27 .....Revision STC-00A
1.2-28 .....Revision STC-01B

List of Effective Pages (Continued)

1.2-29 .....Revision STC-01B
1.2-30 .....Revision STC-01B
1.2-31 .....Revision STC-01B
1.2-32 .....Revision STC-01B
1.2-33 .....Revision STC-01B
1.2-34 .....Revision STC-01B
1.2-35 .....Revision STC-01B
1.2-36 .....Revision STC-01B
1.2-37 .....Revision STC-01B
1.2-38 .....Revision STC-01B
1.2-39 .....Revision STC-01B
1.2-40 .....Revision STC-01B
1.3-1 .....Revision STC-00A

Chapter 2

2-i .....Revision STC-00A
2-ii .....Revision STC-00A
2-iii .....Revision STC-00A
2-iv .....Revision STC-00A
2-v .....Revision STC-00A
2-vi .....Revision STC-02A
2-vii .....Revision STC-02A
2-viii .....Revision STC-00A
2-ix .....Revision STC-00A
2-x .....Revision STC-00A
2-xi .....Revision STC-02A
2-xii .....Revision STC-02A
2-xiii .....Revision STC-02A
2-xiv .....Revision STC-01B
2-xv .....Revision STC-01B
2-xvi .....Revision STC-01B
2-xvii .....Revision STC-01B
2-xviii .....Revision STC-01B
2-xix .....Revision STC-02A
2-xx .....Revision STC-01B
2-xxi .....Revision STC-02A
2-xxii .....Revision STC-02A
2-xxiii .....Revision STC-02A
2-xxiv .....Revision STC-02A
2-xxv .....Revision STC-02A
2-xxvi .....Revision STC-02A
2-xxvii .....Revision STC-02A
2-xxviii .....Revision STC-02A
2-xxix .....Revision STC-01B
2-xxx .....Revision STC-02A
2-xxxi .....Revision STC-02A
2-xxxii .....Revision STC-02A
2-xxxiii .....Revision STC-02A
2-xxxiv .....Revision STC-02A
2-xxxv .....Revision STC-02A
2-xxxvi .....Revision STC-02A
2-xxxvii .....Revision STC-02A
2-xxxviii .....Revision STC-02A
2-xxxix .....Revision STC-01B
2-xl .....Revision STC-01B
2-xli .....Revision STC-01B
2-xlii .....Revision STC-01B
2-xliii .....Revision STC-01B
2-xliv .....Revision STC-01B
2-xlv .....Revision STC-01B
2-xlvi .....Revision STC-01B
2-xlvii .....Revision STC-01B
2-xlviii .....Revision STC-01B
2-xlix .....Revision STC-01B
2-l .....Revision STC-01B
2-li .....Revision STC-01B
2-lii .....Revision STC-01B
2-liii .....Revision STC-01B
2-liv .....Revision STC-01B

List of Effective Pages (Continued)

2-lv .....Revision STC-01B
2-lvi .....Revision STC-01B
2-lvii .....Revision STC-01B
2-lviii .....Revision STC-01B
2-lix .....Revision STC-01B
2-1 .....Revision STC-00A
2.1.1-1 .....Revision STC-02A
2.1.1-2 .....Revision STC-00A
2.1.1-3 .....Revision STC-00A
2.1.1-4 .....Revision STC-00A
2.1.2-1 .....Revision STC-00A
2.1.2-2 .....Revision STC-00A
2.1.2-3 ..... Revision 10
2.1.2-4 ..... Revision 10
2.1.2-5 ..... Revision 10
2.1.3-1 ..... Revision 10
2.1.3-2 ..... Revision 10
2.1.3-3 ..... Revision 10
2.1.3-4 ..... Revision 10
2.1.3-5 ..... Revision 10
2.1.3-6 ..... Revision 10
2.1.3-7 ..... Revision 10
2.1.3-8 .....Revision STC-02A
2.1.3-9 .....Revision STC-02A
2.1.3-10 .....Revision STC-00A
2.1.3-11 .....Revision STC-00A
2.1.3-12 .....Revision STC-00A
2.1.3-13 .....Revision STC-00A
2.1.3-14 .....Revision STC-00A
2.1.3-15 .....Revision STC-00A
2.2-1 .....Revision STC-00A
2.2-2 .....Revision STC-00A
2.2-3 .....Revision STC-00A
2.2-4 .....Revision STC-00A
2.2-5 .....Revision STC-00A
2.2-6 .....Revision STC-00A
2.2-7 .....Revision STC-01B
2.3.1-1 .....Revision STC-00A
2.3.1-2 .....Revision STC-00A
2.3.2-1 .....Revision STC-00A
2.3.2-2 ..... Revision 10
2.3.2-3 ..... Revision 10
2.3.2-4 ..... Revision 10
2.3.2-5 ..... Revision 10
2.3.3-1 ..... Revision 2
2.3.3-2 ..... Revision 10
2.3.4-1 ..... Revision 1
2.3.4-2 ..... Revision 2
2.3.4-3 ..... Revision 2
2.3.5-1 .....Revision STC-00A
2.3.5-2 .....Revision STC-00A
2.3.6-1 .....Revision STC-00A
2.3.6-2 .....Revision STC-00A
2.3.6-3 ..... Revision 1
2.3.6-4 .....Revision STC-00A
2.3.6-5 ..... Revision 1
2.3.7-1 .....Revision STC-02A
2.3.8-1 .....Revision STC-02A
2.4-1 ..... Revision 10
2.4.1-1 ..... Revision 10
2.4.2-1 ..... Revision 10
2.4.3-1 ..... Revision 1
2.4.4-1 .....Revision STC-00A
2.4.4-2 .....Revision STC-00A
2.4.4-3 .....Revision STC-00A
2.4.4-4 .....Revision STC-00A
2.4.4-5 .....Revision STC-00A
2.4.4-6 .....Revision STC-00A
2.4.4-7 .....Revision STC-00A
2.4.4-8 .....Revision STC-00A

List of Effective Pages (Continued)

2.4.4-9 .....Revision STC-00A
2.4.4-10 .....Revision STC-00A
2.4.5-1 ..... Revision 1
2.4.6-1 ..... Revision 1
2.5.1-1 .....Revision STC-00A
2.5.1-2 .....Revision STC-01B
2.5.1-3 .....Revision STC-01B
2.5.1-4 .....Revision STC-01B
2.5.1-5 .....Revision STC-01B
2.5.1-6 .....Revision STC-01B
2.5.1-7 .....Revision STC-01B
2.5.1-8 .....Revision STC-01B
2.5.1-9 .....Revision STC-01B
2.5.1-10 .....Revision STC-01B
2.5.1-11 .....Revision STC-01B
2.5.1-12 .....Revision STC-01B
2.5.1-13 .....Revision STC-00A
2.5.1-14 .....Revision STC-00A
2.5.1-15 .....Revision STC-00A
2.5.1-16 .....Revision STC-00A
2.5.1-17 .....Revision STC-02A
2.5.1-18 .....Revision STC-02A
2.5.1-19 .....Revision STC-02A
2.5.1-20 .....Revision STC-02A
2.5.1-21 .....Revision STC-02A
2.5.1-22 .....Revision STC-02A
2.5.1-23 .....Revision STC-02A
2.5.1-24 .....Revision STC-02A
2.5.1-25 .....Revision STC-02A
2.5.1-26 .....Revision STC-02A
2.5.1-27 .....Revision STC-02A
2.5.1-28 .....Revision STC-02A
2.5.1-29 .....Revision STC-02A
2.5.1-30 .....Revision STC-02A
2.5.1-31 .....Revision STC-02A
2.5.1-32 .....Revision STC-02A
2.5.1-33 .....Revision STC-02A
2.5.1-34 .....Revision STC-02A
2.5.2-1 .....Revision STC-00A
2.5.2-2 .....Revision STC-00A
2.5.2-3 .....Revision STC-00A
2.5.2-4 .....Revision STC-00A
2.5.2-5 .....Revision STC-00A
2.5.2-6 .....Revision STC-00A
2.5.2-7 .....Revision STC-00A
2.5.2-8 .....Revision STC-00A
2.5.2-9 .....Revision STC-00A
2.5.2-10 .....Revision STC-00A
2.5.2-11 .....Revision STC-00A
2.5.2-12 .....Revision STC-00A
2.5.2-13 .....Revision STC-00A
2.5.2-14 .....Revision STC-00A
2.5.2-15 .....Revision STC-00A
2.5.2-16 .....Revision STC-00A
2.5.2-17 .....Revision STC-00A
2.5.2-18 .....Revision STC-00A
2.5.2-19 .....Revision STC-00A
2.5.2-20 .....Revision STC-00A
2.5.2-21 .....Revision STC-00A
2.5.2-22 .....Revision STC-00A
2.5.2-23 .....Revision STC-00A
2.5.2-24 .....Revision STC-00A
2.5.2-25 .....Revision STC-00A
2.5.2-26 .....Revision STC-00A
2.5.2-27 .....Revision STC-00A
2.5.2-28 .....Revision STC-00A
2.5.2-29 .....Revision STC-00A
2.6-1 .....Revision STC-00A
2.6-2 .....Revision STC-00A
2.6.1-1 .....Revision STC-02A

List of Effective Pages (Continued)

2.6.1-2 .....Revision STC-00A
2.6.1-3 .....Revision STC-00A
2.6.1-4 .....Revision STC-00A
2.6.1-5 .....Revision STC-00A
2.6.1-6 .....Revision STC-02A
2.6.1-7 .....Revision STC-00A
2.6.2-1 .....Revision STC-02A
2.6.2-2 .....Revision STC-00A
2.6.2-3 .....Revision STC-00A
2.6.2-4 .....Revision STC-00A
2.6.2-5 .....Revision STC-00A
2.6.2-6 .....Revision STC-00A
2.6.2-7 .....Revision STC-02A
2.6.2-8 .....Revision STC-00A
2.6.3-1 .....Revision STC-00A
2.6.4-1 .....Revision STC-00A
2.6.5-1 .....Revision STC-01B
2.6.5-2 .....Revision STC-01B
2.6.6-1 .....Revision STC-00A
2.6.7-1 .....Revision STC-00A
2.6.7.1-1 .....Revision STC-00A
2.6.7.1-2 .....Revision STC-02A
2.6.7.1-3 .....Revision STC-00A
2.6.7.1-4 .....Revision STC-00A
2.6.7.1-5 .....Revision STC-00A
2.6.7.1-6 .....Revision STC-00A
2.6.7.1-7 .....Revision STC-00A
2.6.7.1-8 .....Revision STC-00A
2.6.7.1-9 .....Revision STC-02A
2.6.7.1-10 .....Revision STC-00A
2.6.7.1-11 .....Revision STC-02A
2.6.7.1-12 .....Revision STC-02A
2.6.7.1-13 .....Revision STC-02A
2.6.7.1-14 .....Revision STC-02A
2.6.7.1-15 .....Revision STC-02A
2.6.7.1-16 .....Revision STC-02A
2.6.7.1-17 .....Revision STC-02A
2.6.7.2-1 .....Revision STC-00A
2.6.7.2-2 .....Revision STC-02A
2.6.7.2-3 .....Revision STC-00A
2.6.7.2-4 .....Revision STC-00A
2.6.7.2-5 .....Revision STC-00A
2.6.7.2-6 .....Revision STC-00A
2.6.7.2-7 .....Revision STC-00A
2.6.7.2-8 .....Revision STC-00A
2.6.7.2-9 .....Revision STC-00A
2.6.7.2-10 .....Revision STC-00A
2.6.7.2-11 .....Revision STC-02A
2.6.7.2-12 .....Revision STC-00A
2.6.7.2-13 .....Revision STC-00A
2.6.7.2-14 .....Revision STC-00A
2.6.7.2-15 .....Revision STC-00A
2.6.7.2-16 .....Revision STC-00A
2.6.7.2-17 .....Revision STC-00A
2.6.7.2-18 .....Revision STC-00A
2.6.7.2-19 .....Revision STC-00A
2.6.7.3-1 .....Revision STC-00A
2.6.7.3-2 .....Revision STC-00A
2.6.7.3-3 .....Revision STC-02A
2.6.7.3-4 .....Revision STC-00A
2.6.7.3-5 .....Revision STC-00A
2.6.7.3-6 ..... Revision 10
2.6.7.3-7 ..... Revision 10
2.6.7.3-8 .....Revision STC-00A
2.6.7.3-9 .....Revision STC-00A
2.6.7.3-10 ..... Revision 10
2.6.7.3-11 .....Revision STC-00A
2.6.7.4-1 .....Revision STC-02A
2.6.7.4-2 .....Revision STC-02A
2.6.7.4-3 .....Revision STC-00A

List of Effective Pages (Continued)

2.6.7.4-4 .....Revision STC-00A
2.6.7.4-5 .....Revision STC-00A
2.6.7.4-6 .....Revision STC-00A
2.6.7.4-7 .....Revision STC-00A
2.6.7.4-8 .....Revision STC-00A
2.6.7.4-9 .....Revision STC-00A
2.6.7.4-10 .....Revision STC-00A
2.6.7.4-11 .....Revision STC-00A
2.6.7.4-12 .....Revision STC-00A
2.6.7.4-13 .....Revision STC-00A
2.6.7.4-14 .....Revision STC-00A
2.6.7.4-15 .....Revision STC-00A
2.6.7.4-16 .....Revision STC-00A
2.6.7.4-17 .....Revision STC-00A
2.6.7.4-18 .....Revision STC-00A
2.6.7.4-19 .....Revision STC-00A
2.6.7.4-20 .....Revision STC-00A
2.6.7.4-21 .....Revision STC-00A
2.6.7.4-22 .....Revision STC-00A
2.6.7.4-23 .....Revision STC-00A
2.6.7.4-24 .....Revision STC-00A
2.6.7.4-25 .....Revision STC-00A
2.6.7.4-26 .....Revision STC-00A
2.6.7.4-27 .....Revision STC-00A
2.6.7.4-28 .....Revision STC-00A
2.6.7.4-29 .....Revision STC-00A
2.6.7.4-30 .....Revision STC-00A
2.6.7.4-31 .....Revision STC-00A
2.6.7.4-32 .....Revision STC-00A
2.6.7.4-33 .....Revision STC-00A
2.6.7.4-34 .....Revision STC-00A
2.6.7.4-35 .....Revision STC-00A
2.6.7.4-36 .....Revision STC-00A
2.6.7.4-37 .....Revision STC-00A
2.6.7.4-38 .....Revision STC-00A
2.6.7.4-39 .....Revision STC-02A
2.6.7.4-40 .....Revision STC-01B
2.6.7.4-41 .....Revision STC-01B
2.6.7.4-42 .....Revision STC-01B
2.6.7.4-43 .....Revision STC-02A
2.6.7.4-44 .....Revision STC-01B
2.6.7.4-45 .....Revision STC-02A
2.6.7.4-46 .....Revision STC-02A
2.6.7.4-47 .....Revision STC-02A
2.6.7.4-48 .....Revision STC-01B
2.6.7.4-49 .....Revision STC-01B
2.6.7.4-50 .....Revision STC-01B
2.6.7.4-51 .....Revision STC-01B
2.6.7.4-52 .....Revision STC-01B
2.6.7.4-53 .....Revision STC-01B
2.6.7.4-54 .....Revision STC-01B
2.6.7.4-55 .....Revision STC-01B
2.6.7.4-56 .....Revision STC-01B
2.6.7.4-57 .....Revision STC-01B
2.6.7.4-58 .....Revision STC-02A
2.6.7.4-59 .....Revision STC-02A
2.6.7.5-1 ..... Revision 2
2.6.7.5-2 .....Revision STC-02A
2.6.7.5-3 ..... Revision 10
2.6.7.5-4 .....Revision STC-01B
2.6.7.5-5 .....Revision STC-01B
2.6.7.5-6 .....Revision STC-01B
2.6.7.5-7 .....Revision STC-01B
2.6.7.5-8 .....Revision STC-01B
2.6.7.5-9 .....Revision STC-01B
2.6.7.5-10 .....Revision STC-01B
2.6.7.5-11 .....Revision STC-01B
2.6.7.5-12 .....Revision STC-01B
2.6.7.5-13 .....Revision STC-01B
2.6.7.6-1 .....Revision STC-00A

List of Effective Pages (Continued)

2.6.7.6-2 .....Revision STC-00A
2.6.7.6-3 .....Revision STC-00A
2.6.7.6-4 .....Revision STC-00A
2.6.7.6-5 .....Revision STC-00A
2.6.7.6-6 .....Revision STC-00A
2.6.7.6-7 .....Revision STC-00A
2.6.7.6-8 .....Revision STC-00A
2.6.7.6-9 .....Revision STC-00A
2.6.7.6-10 .....Revision STC-00A
2.6.7.6-11 .....Revision STC-00A
2.6.7.6-12 .....Revision STC-00A
2.6.7.6-13 .....Revision STC-00A
2.6.7.7-1 .....Revision STC-00A
2.6.7.7-2 .....Revision STC-00A
2.6.7.7-3 .....Revision STC-00A
2.6.7.7-4 .....Revision STC-00A
2.6.7.7-5 .....Revision STC-00A
2.6.8-1 .....Revision STC-00A
2.6.9-1 .....Revision STC-00A
2.6.10-1 .....Revision STC-00A
2.6.10.1-1 .....Revision STC-02A
2.6.10.1-2 .....Revision STC-02A
2.6.10.2-1 ..... Revision 1
2.6.10.2-2 ..... Revision 1
2.6.10.2-3 ..... Revision 1
2.6.10.2-4 ..... Revision 1
2.6.10.3-1 ..... Revision 1
2.6.10.3-2 ..... Revision 2
2.6.10.3-3 ..... Revision 1
2.6.10.3-4 ..... Revision 1
2.6.10.3-5 ..... Revision 1
2.6.10.3-6 ..... Revision 1
2.6.10.3-7 ..... Revision 1
2.6.11-1 .....Revision STC-00A
2.6.11-2 ..... Revision 2
2.6.11.1-1 ..... Revision 2
2.6.11.1-2 ..... Revision 2
2.6.11.1-3 ..... Revision 2
2.6.11.1-4 ..... Revision 2
2.6.11.2-1 ..... Revision 2
2.6.11.2-2 ..... Revision 2
2.6.11.2-3 ..... Revision 2
2.6.11.2-4 ..... Revision 2
2.6.11.2-5 ..... Revision 2
2.6.11.2-6 ..... Revision 2
2.6.11.2-7 ..... Revision 2
2.6.11.2-8 ..... Revision 2
2.6.11.2-9 ..... Revision 2
2.6.11.2-10 ..... Revision 2
2.6.11.2-11 ..... Revision 2
2.6.11.2-12 ..... Revision 2
2.6.11.3-1 ..... Revision 2
2.6.12-1 .....Revision STC-00A
2.6.12-2 .....Revision STC-00A
2.6.12-3 .....Revision STC-00A
2.6.12-4 .....Revision STC-00A
2.6.12-5 .....Revision STC-00A
2.6.12.1-1 ..... Revision 10
2.6.12.2-1 ..... Revision 10
2.6.12.2-2 ..... Revision 10
2.6.12.2-3 ..... Revision 10
2.6.12.2-4 ..... Revision 10
2.6.12.2-5 ..... Revision 10
2.6.12.2-6 ..... Revision 10
2.6.12.3-1 ..... Revision 10
2.6.12.3-2 ..... Revision 10
2.6.12.3-3 ..... Revision 10
2.6.12.3-4 ..... Revision 10
2.6.12.3-5 ..... Revision 10
2.6.12.3-6 ..... Revision 10

List of Effective Pages (Continued)

2.6.12.3-7 ..... Revision 10
2.6.12.4-1 .....Revision STC-00A
2.6.12.4-2 ..... Revision 10
2.6.12.4-3 ..... Revision 10
2.6.12.5-1 ..... Revision 10
2.6.12.5-2 ..... Revision 10
2.6.12.5-3 ..... Revision 10
2.6.12.6-1 ..... Revision 10
2.6.12.6-2 ..... Revision 10
2.6.12.7-1 .....Revision STC-00A
2.6.12.7-2 ..... Revision 10
2.6.12.7-3 ..... Revision 10
2.6.12.7-4 ..... Revision 10
2.6.12.7-5 ..... Revision 10
2.6.12.7-6 ..... Revision 10
2.6.12.7-7 ..... Revision 10
2.6.12.7-8 ..... Revision 10
2.6.12.7-9 ..... Revision 10
2.6.12.7-10 ..... Revision 10
2.6.12.7-11 ..... Revision 10
2.6.12.7-12 ..... Revision 10
2.6.12.7-13 ..... Revision 10
2.6.12.7-14 ..... Revision 10
2.6.12.7-15 ..... Revision 10
2.6.12.7-16 ..... Revision 10
2.6.12.7-17 ..... Revision 10
2.6.12.7-18 ..... Revision 10
2.6.12.7-19 ..... Revision 10
2.6.12.7-20 ..... Revision 10
2.6.12.7-21 ..... Revision 10
2.6.12.7-22 ..... Revision 10
2.6.12.8-1 ..... Revision 10
2.6.12.8-2 ..... Revision 10
2.6.12.9-1 ..... Revision 10
2.6.12.9-2 ..... Revision 10
2.6.12.9-3 ..... Revision 10
2.6.12.9-4 ..... Revision 10
2.6.12.9-5 ..... Revision 10
2.6.12.9-6 ..... Revision 10
2.6.12.9-7 ..... Revision 10
2.6.12.9-8 ..... Revision 10
2.6.12.9-9 ..... Revision 10
2.6.12.9-10 ..... Revision 10
2.6.12.9-11 ..... Revision 10
2.6.12.10-1 ..... Revision 10
2.6.12.11-1 ..... Revision 10
2.6.12.12-1 ..... Revision 10
2.6.12.13-1 ..... Revision 10
2.6.12.13-2 ..... Revision 10
2.6.12.13-3 ..... Revision 10
2.6.12.13-4 ..... Revision 10
2.6.13-1 .....Revision STC-00A
2.6.13-2 .....Revision STC-00A
2.6.13-3 .....Revision STC-00A
2.6.13.1-1 .....Revision STC-00A
2.6.13.1-2 .....Revision STC-00A
2.6.13.2-1 .....Revision STC-00A
2.6.13.2-2 ..... Revision 10
2.6.13.2-3 .....Revision STC-00A
2.6.13.2-4 .....Revision STC-00A
2.6.13.2-5 .....Revision STC-00A
2.6.13.2-6 .....Revision STC-00A
2.6.13.2-7 .....Revision STC-00A
2.6.13.3-1 .....Revision STC-00A
2.6.13.3-2 .....Revision STC-00A
2.6.13.3-3 .....Revision STC-00A
2.6.13.3-4 .....Revision STC-00A
2.6.13.4-1 .....Revision STC-00A
2.6.13.4-2 .....Revision STC-00A
2.6.13.4-3 .....Revision STC-00A

List of Effective Pages (Continued)

2.6.13.4-4 .....Revision STC-00A
2.6.13.4-5 .....Revision STC-00A
2.6.13.5-1 .....Revision STC-00A
2.6.13.5-2 .....Revision STC-00A
2.6.13.6-1 .....Revision STC-00A
2.6.13.6-2 .....Revision STC-00A
2.6.13.7-1 .....Revision STC-00A
2.6.13.7-2 .....Revision STC-00A
2.6.13.8-1 .....Revision STC-00A
2.6.13.9-1 .....Revision STC-00A
2.6.13.10-1 .....Revision STC-00A
2.6.13.11-1 .....Revision STC-00A
2.6.13.11-2 ..... Revision 10
2.6.13.11-3 .....Revision STC-00A
2.6.13.12-1 .....Revision STC-00A
2.6.13.12-2 .....Revision STC-00A
2.6.14-1 .....Revision STC-00A
2.6.14-2 .....Revision STC-00A
2.6.14-3 .....Revision STC-00A
2.6.14-4 .....Revision STC-00A
2.6.14-5 .....Revision STC-00A
2.6.14-6 .....Revision STC-00A
2.6.14-7 .....Revision STC-00A
2.6.14-8 .....Revision STC-00A
2.6.14-9 ..... Revision 10
2.6.14-10 .....Revision STC-00A
2.6.14-11 .....Revision STC-00A
2.6.14-12 .....Revision STC-00A
2.6.14-13 .....Revision STC-00A
2.6.14-14 .....Revision STC-00A
2.6.14-15 .....Revision STC-00A
2.6.14-16 .....Revision STC-00A
2.6.14-17 .....Revision STC-00A
2.6.14-18 .....Revision STC-00A
2.6.14-19 .....Revision STC-00A
2.6.14-20 .....Revision STC-00A
2.6.14-21 .....Revision STC-00A
2.6.14-22 .....Revision STC-00A
2.6.14-23 .....Revision STC-00A
2.6.14-24 .....Revision STC-00A
2.6.14-25 ..... Revision 10
2.6.14-26 .....Revision STC-00A
2.6.14-27 ..... Revision 10
2.6.14-28 .....Revision STC-00A
2.6.14-29 .....Revision STC-00A
2.6.14-30 .....Revision STC-00A
2.6.14-31 .....Revision STC-00A
2.6.14-32 .....Revision STC-00A
2.6.14-33 .....Revision STC-00A
2.6.14-34 .....Revision STC-00A
2.6.14-35 .....Revision STC-00A
2.6.14-36 .....Revision STC-00A
2.6.14-37 .....Revision STC-00A
2.6.14-38 .....Revision STC-00A
2.6.14-39 .....Revision STC-00A
2.6.14-40 .....Revision STC-00A
2.6.14-41 .....Revision STC-00A
2.6.14-42 .....Revision STC-00A
2.6.14-43 .....Revision STC-00A
2.6.14-44 .....Revision STC-00A
2.6.14-45 .....Revision STC-00A
2.6.14-46 .....Revision STC-00A
2.6.14-47 .....Revision STC-00A
2.6.14-48 .....Revision STC-00A
2.6.14-49 .....Revision STC-00A
2.6.14-50 .....Revision STC-00A
2.6.14-51 .....Revision STC-00A
2.6.14-52 .....Revision STC-00A
2.6.14-53 .....Revision STC-00A
2.6.14-54 .....Revision STC-00A

List of Effective Pages (Continued)

2.6.14-55 .....Revision STC-00A
2.6.14-56 .....Revision STC-00A
2.6.14-57 .....Revision STC-00A
2.6.14-58 .....Revision STC-00A
2.6.14-59 .....Revision STC-00A
2.6.14-60 .....Revision STC-00A
2.6.14-61 ..... Revision 10
2.6.14-62 ..... Revision 10
2.6.14-63 ..... Revision 10
2.6.14-64 .....Revision STC-00A
2.6.15-1 .....Revision STC-00A
2.6.15.1-1 .....Revision STC-00A
2.6.15.1-2 .....Revision STC-00A
2.6.15.2-1 .....Revision STC-00A
2.6.15.2-2 .....Revision STC-00A
2.6.15.2-3 .....Revision STC-00A
2.6.15.2-4 .....Revision STC-00A
2.6.15.2-5 .....Revision STC-00A
2.6.15.2-6 .....Revision STC-00A
2.6.15.2-7 .....Revision STC-00A
2.6.15.3-1 .....Revision STC-00A
2.6.15.3-2 .....Revision STC-00A
2.6.15.3-3 .....Revision STC-00A
2.6.15.3-4 .....Revision STC-00A
2.6.15.4-1 .....Revision STC-00A
2.6.15.4-2 .....Revision STC-00A
2.6.15.4-3 .....Revision STC-00A
2.6.15.4-4 .....Revision STC-00A
2.6.15.4-5 .....Revision STC-00A
2.6.15.5-1 .....Revision STC-00A
2.6.15.6-1 .....Revision STC-00A
2.6.15.6-2 .....Revision STC-00A
2.6.15.6-3 .....Revision STC-00A
2.6.15.7-1 .....Revision STC-00A
2.6.15.8-1 .....Revision STC-00A
2.6.15.9-1 .....Revision STC-00A
2.6.15.10-1 .....Revision STC-00A
2.6.15.11-1 .....Revision STC-01B
2.6.15.11-2 .....Revision STC-01B
2.6.15.12-1 .....Revision STC-00A
2.6.15.12-2 .....Revision STC-00A
2.6.16-1 .....Revision STC-00A
2.6.16-2 .....Revision STC-00A
2.6.16-3 .....Revision STC-00A
2.6.16-4 .....Revision STC-00A
2.6.16-5 .....Revision STC-00A
2.6.16-6 .....Revision STC-00A
2.6.16-7 .....Revision STC-00A
2.6.16-8 .....Revision STC-00A
2.6.16-9 .....Revision STC-00A
2.6.16-10 .....Revision STC-00A
2.6.16-11 .....Revision STC-00A
2.6.16-12 .....Revision STC-02A
2.6.16-13 .....Revision STC-00A
2.6.16-14 .....Revision STC-00A
2.6.16-15 .....Revision STC-02A
2.6.16-16 .....Revision STC-00A
2.6.16-17 .....Revision STC-00A
2.6.16-18 .....Revision STC-00A
2.6.16-19 .....Revision STC-00A
2.6.16-20 .....Revision STC-00A
2.6.16-21 .....Revision STC-00A
2.6.16-22 .....Revision STC-00A
2.6.16-23 .....Revision STC-02A
2.6.16-24 .....Revision STC-02A
2.6.16-25 .....Revision STC-02A
2.6.16-26 .....Revision STC-02A
2.6.16-27 .....Revision STC-02A
2.6.16-28 .....Revision STC-02A
2.6.16-29 .....Revision STC-02A

List of Effective Pages (Continued)

2.6.16-30 .....Revision STC-02A
2.6.16-31 .....Revision STC-02A
2.6.16-32 .....Revision STC-02A
2.6.16-33 .....Revision STC-02A
2.6.16-34 .....Revision STC-02A
2.6.16-35 .....Revision STC-02A
2.6.16-36 .....Revision STC-02A
2.6.16-37 .....Revision STC-02A
2.6.16-38 .....Revision STC-02A
2.6.16-39 .....Revision STC-02A
2.6.16-40 .....Revision STC-02A
2.6.16-41 .....Revision STC-02A
2.6.16-42 .....Revision STC-02A
2.6.16-43 .....Revision STC-02A
2.6.16-44 .....Revision STC-02A
2.6.16-45 .....Revision STC-02A
2.6.16-46 .....Revision STC-02A
2.6.16-47 .....Revision STC-02A
2.6.16-48 .....Revision STC-02A
2.6.16-49 .....Revision STC-02A
2.6.16-50 .....Revision STC-02A
2.6.16-51 .....Revision STC-02A
2.6.16-52 .....Revision STC-02A
2.6.16-53 .....Revision STC-02A
2.6.16-54 .....Revision STC-02A
2.6.16-55 .....Revision STC-02A
2.6.16-56 .....Revision STC-02A
2.6.16-57 .....Revision STC-02A
2.6.16-58 .....Revision STC-02A
2.6.16-59 .....Revision STC-02A
2.6.16-60 .....Revision STC-02A
2.6.17-1 .....Revision STC-00A
2.6.17-2 .....Revision STC-00A
2.6.17-3 .....Revision STC-00A
2.6.17-4 .....Revision STC-00A
2.6.17-5 .....Revision STC-00A
2.6.17-6 .....Revision STC-00A
2.6.17-7 .....Revision STC-00A
2.6.17-8 .....Revision STC-00A
2.6.17-9 .....Revision STC-00A
2.6.17-10 .....Revision STC-00A
2.6.17-11 .....Revision STC-00A
2.6.17-12 .....Revision STC-00A
2.6.17-13 .....Revision STC-00A
2.6.18-1 .....Revision STC-00A
2.6.18-2 .....Revision STC-00A
2.6.18-3 .....Revision STC-00A
2.6.18-4 .....Revision STC-00A
2.6.18-5 .....Revision STC-00A
2.6.18-6 .....Revision STC-00A
2.6.19-1 .....Revision STC-00A
2.6.19-2 .....Revision STC-00A
2.6.19-3 .....Revision STC-00A
2.6.19-4 .....Revision STC-00A
2.6.19-5 .....Revision STC-00A
2.6.19-6 .....Revision STC-00A
2.6.19-7 .....Revision STC-01B
2.6.19-8 .....Revision STC-01B
2.6.19-9 .....Revision STC-01B
2.6.19-10 .....Revision STC-01B
2.6.19-11 .....Revision STC-02A
2.6.19-12 .....Revision STC-02A
2.6.19-13 .....Revision STC-02A
2.6.19-14 .....Revision STC-00A
2.6.19-15 .....Revision STC-01B
2.6.19-16 .....Revision STC-01B
2.6.19-17 .....Revision STC-01B
2.6.19-18 .....Revision STC-01B
2.6.19-19 .....Revision STC-02A
2.6.19-20 .....Revision STC-01B

List of Effective Pages (Continued)

2.6.19-21 .....Revision STC-01B
2.6.19-22 .....Revision STC-02A
2.6.19-23 .....Revision STC-01B
2.7-1 .....Revision STC-00A
2.7-2 .....Revision STC-00A
2.7.1-1 .....Revision STC-00A
2.7.1-2 .....Revision STC-00A
2.7.1.1-1 .....Revision STC-00A
2.7.1.1-2 .....Revision STC-02A
2.7.1.1-3 .....Revision STC-00A
2.7.1.1-4 .....Revision STC-00A
2.7.1.1-5 .....Revision STC-00A
2.7.1.1-6 ..... Revision 10
2.7.1.1-7 .....Revision STC-00A
2.7.1.1-8 .....Revision STC-00A
2.7.1.1-9 .....Revision STC-02A
2.7.1.1-10 .....Revision STC-00A
2.7.1.1-11 .....Revision STC-02A
2.7.1.1-12 .....Revision STC-02A
2.7.1.1-13 .....Revision STC-02A
2.7.1.1-14 .....Revision STC-02A
2.7.1.1-15 .....Revision STC-02A
2.7.1.2-1 .....Revision STC-00A
2.7.1.2-2 .....Revision STC-02A
2.7.1.2-3 .....Revision STC-00A
2.7.1.2-4 .....Revision STC-00A
2.7.1.2-5 .....Revision STC-00A
2.7.1.2-6 ..... Revision 1
2.7.1.2-7 ..... Revision 10
2.7.1.2-8 ..... Revision 2
2.7.1.2-9 .....Revision STC-00A
2.7.1.2-10 .....Revision STC-00A
2.7.1.2-11 .....Revision STC-00A
2.7.1.2-12 .....Revision STC-00A
2.7.1.2-13 .....Revision STC-00A
2.7.1.2-14 .....Revision STC-00A
2.7.1.2-15 .....Revision STC-00A
2.7.1.2-16 .....Revision STC-00A
2.7.1.3-1 ..... Revision 10
2.7.1.3-2 .....Revision STC-02A
2.7.1.3-3 .....Revision STC-00A
2.7.1.3-4 ..... Revision 10
2.7.1.3-5 ..... Revision 10
2.7.1.3-6 ..... Revision 10
2.7.1.3-7 .....Revision STC-00A
2.7.1.3-8 .....Revision STC-00A
2.7.1.3-9 .....Revision STC-00A
2.7.1.4-1. .....Revision STC-00A
2.7.1.4-2 .....Revision STC-02A
2.7.1.4-3 .....Revision STC-00A
2.7.1.4-4 .....Revision STC-00A
2.7.1.4-5 .....Revision STC-00A
2.7.1.4-6 ..... Revision 10
2.7.1.4-7 ..... Revision 1
2.7.1.4-8 ..... Revision 1
2.7.1.4-9 ..... Revision 10
2.7.1.4-10 ..... Revision 1
2.7.1.4-11 ..... Revision 10
2.7.1.4-12 .....Revision STC-00A
2.7.1.5-1 .....Revision STC-00A
2.7.1.5-2 .....Revision STC-00A
2.7.1.5-3 .....Revision STC-00A
2.7.1.6-1 .....Revision STC-00A
2.7.1.6-2 .....Revision STC-00A
2.7.1.6-3 .....Revision STC-00A
2.7.1.6-4 .....Revision STC-00A
2.7.1.6-5 .....Revision STC-00A
2.7.1.6-6 .....Revision STC-00A
2.7.1.6-7 .....Revision STC-01B
2.7.1.6-8 .....Revision STC-01B

List of Effective Pages (Continued)

2.7.1.6-9 .....Revision STC-00A
2.7.1.6-10 .....Revision STC-00A
2.7.1.6-11 .....Revision STC-00A
2.7.1.6-12 .....Revision STC-00A
2.7.1.6-13 .....Revision STC-00A
2.7.1.6-14 .....Revision STC-01B
2.7.1.6-15 .....Revision STC-01B
2.7.1.6-16 .....Revision STC-01B
2.7.2-1 ..... Revision 10
2.7.2.1-1 .....Revision STC-00A
2.7.2.1-2 .....Revision STC-00A
2.7.2.1-3 .....Revision STC-00A
2.7.2.1-4 .....Revision STC-00A
2.7.2.1-5 .....Revision STC-00A
2.7.2.2-1 .....Revision STC-00A
2.7.2.2-2 .....Revision STC-00A
2.7.2.2-3 .....Revision STC-00A
2.7.2.2-4 .....Revision STC-00A
2.7.2.2-5 .....Revision STC-00A
2.7.2.2-6 .....Revision STC-00A
2.7.2.2-7 .....Revision STC-00A
2.7.2.2-8 .....Revision STC-00A
2.7.2.2-9 .....Revision STC-00A
2.7.2.3-1 .....Revision STC-00A
2.7.2.3-2 .....Revision STC-00A
2.7.2.3-3 .....Revision STC-00A
2.7.2.3-4 .....Revision STC-00A
2.7.2.3-5 .....Revision STC-00A
2.7.2.3-6 .....Revision STC-00A
2.7.2.4-1 ..... Revision 1
2.7.2.4-2 ..... Revision 1
2.7.2.4-3 ..... Revision 1
2.7.2.4-4 ..... Revision 1
2.7.2.4-5 ..... Revision 1
2.7.2.4-6 ..... Revision 1
2.7.2.4-7 ..... Revision 1
2.7.2.5-1 .....Revision STC-00A
2.7.2.6-1 .....Revision STC-00A
2.7.3.1-1 ..... Revision 10
2.7.3.2-1 .....Revision STC-00A
2.7.3.2-2 .....Revision STC-00A
2.7.3.2-3 .....Revision STC-00A
2.7.3.2-4 .....Revision STC-00A
2.7.3.2-5 .....Revision STC-00A
2.7.3.3-1 ..... Revision 1
2.7.3.3-2 ..... Revision 10
2.7.3.3-3 ..... Revision 10
2.7.3.4-1 ..... Revision 10
2.7.3.4-2 ..... Revision 1
2.7.3.5-1 ..... Revision 1
2.7.3.6-1 ..... Revision 1
2.7.4-1 ..... Revision 10
2.7.5-1 .....Revision STC-00A
2.7.6-1 ..... Revision 10
2.7.7-1 .....Revision STC-00A
2.7.7-2 .....Revision STC-00A
2.7.7-3 .....Revision STC-00A
2.7.7-4 .....Revision STC-00A
2.7.8-1 ..... Revision 10
2.7.8-2 ..... Revision 10
2.7.8-3 ..... Revision 10
2.7.8-4 ..... Revision 10
2.7.8.1-1 ..... Revision 10
2.7.8.1-2 ..... Revision 2
2.7.8.1-3 ..... Revision 10
2.7.8.1-4 ..... Revision 2
2.7.8.1-5 ..... Revision 2
2.7.8.1-6 ..... Revision 10
2.7.8.1-7 ..... Revision 2
2.7.8.1-8 ..... Revision 10

List of Effective Pages (Continued)

2.7.8.1-9 ..... Revision 10
2.7.8.1-10 ..... Revision 2
2.7.8.1-11 ..... Revision 2
2.7.8.1-12 ..... Revision 2
2.7.8.1-13 ..... Revision 2
2.7.8.1-14 ..... Revision 2
2.7.8.1-15 ..... Revision 2
2.7.8.1-16 ..... Revision 2
2.7.8.1-17 ..... Revision 2
2.7.8.1-18 ..... Revision 2
2.7.8.1-19 ..... Revision 2
2.7.8.1-20 ..... Revision 2
2.7.8.1-21 ..... Revision 2
2.7.8.1-22 ..... Revision 2
2.7.8.1-23 ..... Revision 2
2.7.8.1-24 ..... Revision 2
2.7.8.1-25 ..... Revision 2
2.7.8.1-26 ..... Revision 2
2.7.8.1-27 ..... Revision 2
2.7.8.1-28 ..... Revision 2
2.7.8.1-29 ..... Revision 2
2.7.8.1-30 ..... Revision 2
2.7.8.1-31 ..... Revision 2
2.7.8.1-32 ..... Revision 2
2.7.8.1-33 ..... Revision 2
2.7.8.1-34 ..... Revision 2
2.7.8.1-35 ..... Revision 2
2.7.8.1-36 ..... Revision 2
2.7.8.1-37 ..... Revision 2
2.7.8.1-38 ..... Revision 2
2.7.8.1-39 ..... Revision 2
2.7.8.1-40 ..... Revision 2
2.7.8.1-41 ..... Revision 2
2.7.8.1-42 ..... Revision 2
2.7.8.1-43 ..... Revision 2
2.7.8.2-1 ..... Revision STC-00A
2.7.8.2-2 ..... Revision 2
2.7.8.3-1 ..... Revision STC-00A
2.7.8.3-2 ..... Revision STC-00A
2.7.8.3-3 ..... Revision STC-00A
2.7.8.3-4 ..... Revision STC-00A
2.7.8.3-5 ..... Revision STC-00A
2.7.8.3-6 ..... Revision STC-00A
2.7.8.3-7 ..... Revision 10
2.7.8.3-8 ..... Revision 10
2.7.8.3-9 ..... Revision 10
2.7.8.3-10 ..... Revision 2
2.7.8.3-11 ..... Revision 2
2.7.8.3-12 ..... Revision 2
2.7.8.3-13 ..... Revision 2
2.7.8.4-1 ..... Revision STC-00A
2.7.8.4-2 ..... Revision 10
2.7.8.4-3 ..... Revision 5
2.7.8.4-4 ..... Revision 5
2.7.8.4-5 ..... Revision 5
2.7.8.4-6 ..... Revision 5
2.7.8.4-7 ..... Revision 10
2.7.8.4-8 ..... Revision 5
2.7.8.4-9 ..... Revision 5
2.7.8.4-10 ..... Revision 5
2.7.8.5-1 ..... Revision STC-00A
2.7.9-1 ..... Revision STC-00A
2.7.9-2 ..... Revision STC-00A
2.7.9-3 ..... Revision STC-00A
2.7.9-4 ..... Revision STC-00A
2.7.9-5 ..... Revision STC-00A
2.7.9-6 ..... Revision STC-00A
2.7.9-7 ..... Revision STC-00A
2.7.9-8 ..... Revision STC-00A
2.7.9-9 ..... Revision STC-00A

List of Effective Pages (Continued)

2.7.9-10 .....Revision STC-00A
2.7.9-11 .....Revision STC-00A
2.7.9-12 .....Revision STC-00A
2.7.9-13 .....Revision STC-00A
2.7.9-14 .....Revision STC-00A
2.7.9-15 .....Revision STC-00A
2.7.9-16 .....Revision STC-00A
2.7.9-17 .....Revision STC-00A
2.7.9-18 .....Revision STC-00A
2.7.9-19 .....Revision STC-00A
2.7.9-20 .....Revision STC-00A
2.7.9-21 .....Revision STC-00A
2.7.9-22 .....Revision STC-00A
2.7.9-23 ..... Revision 10
2.7.9-24 .....Revision STC-00A
2.7.9-25 ..... Revision 10
2.7.9-26 ..... Revision 10
2.7.9-27 .....Revision STC-00A
2.7.9-28 .....Revision STC-00A
2.7.9-29 .....Revision STC-00A
2.7.9-30 ..... Revision 10
2.7.9-31 .....Revision STC-00A
2.7.9-32 .....Revision STC-00A
2.7.9-33 .....Revision STC-00A
2.7.9-34 .....Revision STC-00A
2.7.9-35 .....Revision STC-00A
2.7.9-36 ..... Revision 10
2.7.9-37 ..... Revision 10
2.7.10-1 .....Revision STC-00A
2.7.10-2 ..... Revision 10
2.7.10-3 .....Revision STC-00A
2.7.10-4 .....Revision STC-00A
2.7.10-5 .....Revision STC-00A
2.7.10-6 .....Revision STC-00A
2.7.10-7 .....Revision STC-00A
2.7.10-8 ..... Revision 10
2.7.10-9 .....Revision STC-02A
2.7.10-10 .....Revision STC-01B
2.7.10-11 .....Revision STC-01B
2.7.10-12 .....Revision STC-01B
2.7.11-1 .....Revision STC-00A
2.7.11-2 ..... Revision 10
2.7.11-3 ..... Revision 11
2.7.11-4 ..... Revision 10
2.7.11-5 ..... Revision 11
2.7.11-6 ..... Revision 11
2.7.11-7 ..... Revision 11
2.7.11-8 ..... Revision 11
2.7.11-9 ..... Revision 10
2.7.11-10 ..... Revision 11
2.7.11-11 .....Revision STC-00A
2.7.11-12 ..... Revision 12
2.7.11-13 ..... Revision 12
2.7.11-14 .....Revision STC-00A
2.7.11-15 .....Revision STC-00A
2.7.11-16 .....Revision STC-00A
2.7.12-1 .....Revision STC-00A
2.7.12-2 .....Revision STC-00A
2.7.12-3 .....Revision STC-00A
2.7.12-4 .....Revision STC-00A
2.7.12-5 .....Revision STC-00A
2.7.12-6 .....Revision STC-00A
2.7.12-7 .....Revision STC-00A
2.7.12-8 .....Revision STC-00A
2.7.12-9 .....Revision STC-00A
2.7.12-10 .....Revision STC-00A
2.7.13-1 .....Revision STC-00A
2.7.13-2 .....Revision STC-00A
2.7.13-3 .....Revision STC-00A
2.7.13-4 .....Revision STC-00A

List of Effective Pages (Continued)

2.7.13.1-1 .....Revision STC-00A
2.7.13.1-2 .....Revision STC-00A
2.7.13.1-3 .....Revision STC-00A
2.7.13.1-4 .....Revision STC-00A
2.7.13.1-5 .....Revision STC-02A
2.7.13.1-6 .....Revision STC-02A
2.7.13.1-7 .....Revision STC-00A
2.7.13.1-8 .....Revision STC-02A
2.7.13.1-9 .....Revision STC-02A
2.7.13.1-10 .....Revision STC-02A
2.7.13.1-11 .....Revision STC-02A
2.7.13.1-12 .....Revision STC-02A
2.7.13.1-13 .....Revision STC-02A
2.7.13.1-14 .....Revision STC-02A
2.7.13.1-15 .....Revision STC-02A
2.7.13.1-16 .....Revision STC-02A
2.7.13.1-17 .....Revision STC-00A
2.7.13.1-18 .....Revision STC-02A
2.7.13.2-1 .....Revision STC-00A
2.7.13.2-2 .....Revision STC-00A
2.7.13.2-3 .....Revision STC-00A
2.7.13.3-1 .....Revision STC-00A
2.7.13.3-2 .....Revision STC-00A
2.7.13.3-3 .....Revision STC-02A
2.7.13.3-4 .....Revision STC-00A
2.7.13.4-1 .....Revision STC-00A
2.7.13.4-2 .....Revision STC-00A
2.7.13.4-3 .....Revision STC-00A
2.7.13.4-4 .....Revision STC-00A
2.7.13.4-5 .....Revision STC-00A
2.7.13.4-6 .....Revision STC-00A
2.7.13.4-7 .....Revision STC-00A
2.7.13.4-8 .....Revision STC-00A
2.7.13.5-1 .....Revision STC-00A
2.7.13.5-2 .....Revision STC-00A
2.7.14-1 .....Revision STC-00A
2.7.14-2 .....Revision STC-00A
2.7.14-3 .....Revision STC-00A
2.7.14-4 .....Revision STC-00A
2.7.14-5 .....Revision STC-00A
2.7.14-6 .....Revision STC-00A
2.7.14-7 .....Revision STC-00A
2.7.14-8 .....Revision STC-00A
2.7.14-9 .....Revision STC-00A
2.7.14-10 .....Revision STC-00A
2.7.14-11 .....Revision STC-00A
2.7.14-12 .....Revision STC-00A
2.7.14-13 .....Revision STC-00A
2.8-1 .....Revision STC-00A
2.9-1 .....Revision STC-00A
2.9-2 .....Revision STC-00A
2.9-3 .....Revision STC-00A
2.9-4 .....Revision STC-00A
2.9-5 ..... Revision 12
2.9-6 ..... Revision 12
2.9-7 ..... Revision 12
2.9-8 ..... Revision 12
2.9-9 ..... Revision 12
2.9-10 .....Revision STC-00A
2.9-11 .....Revision STC-00A
2.10.1-1 .....Revision STC-00A
2.10.1-2 .....Revision STC-00A
2.10.1-3 .....Revision STC-00A
2.10.1-4 .....Revision STC-00A
2.10.2-1 ..... Revision 10
2.10.2-2 ..... Revision 1
2.10.2-3 .....Revision STC-00A
2.10.2-4 .....Revision STC-00A
2.10.2-5 ..... Revision 10
2.10.2-6 ..... Revision 1

List of Effective Pages (Continued)

2.10.2-7 ..... Revision 1
2.10.2-8 ..... Revision 1
2.10.2-9 ..... Revision 1
2.10.2-10 ..... Revision 1
2.10.2-11 ..... Revision 1
2.10.2-12 .....Revision STC-02A
2.10.2-13 .....Revision STC-00A
2.10.2-14 ..... Revision 10
2.10.2-15 .....Revision STC-00A
2.10.2-16 .....Revision STC-00A
2.10.2-17 .....Revision STC-00A
2.10.2-18 .....Revision STC-00A
2.10.2-19 .....Revision STC-00A
2.10.2-20 .....Revision STC-00A
2.10.2-21 .....Revision STC-00A
2.10.2-22 .....Revision STC-00A
2.10.2-23 .....Revision STC-00A
2.10.2-24 .....Revision STC-00A
2.10.2-25 .....Revision STC-02A
2.10.2-26 .....Revision STC-02A
2.10.2-27 .....Revision STC-00A
2.10.2-28 .....Revision STC-00A
2.10.2-29 .....Revision STC-00A
2.10.2-30 .....Revision STC-00A
2.10.2-31 .....Revision STC-00A
2.10.2-32 .....Revision STC-00A
2.10.2-33 .....Revision STC-00A
2.10.2-34 .....Revision STC-00A
2.10.2-35 .....Revision STC-00A
2.10.2-36 ..... Revision 1
2.10.2-37 ..... Revision 1
2.10.2-38 ..... Revision 1
2.10.2-39 ..... Revision 1
2.10.2-40 ..... Revision 1
2.10.2-41 ..... Revision 1
2.10.2-42 ..... Revision 1
2.10.2-43 ..... Revision 1
2.10.2-44 ..... Revision 1
2.10.2-45 ..... Revision 1
2.10.2-46 ..... Revision 1
2.10.2-47 ..... Revision 1
2.10.2-48 ..... Revision 1
2.10.2-49 ..... Revision 1
2.10.2-50 ..... Revision 1
2.10.2-51 ..... Revision 1
2.10.2-52 ..... Revision 1
2.10.2-53 ..... Revision 1
2.10.2-54 ..... Revision 1
2.10.2-55 ..... Revision 1
2.10.2-56 ..... Revision 1
2.10.2-57 ..... Revision 1
2.10.2-58 ..... Revision 1
2.10.2-59 ..... Revision 1
2.10.2-60 ..... Revision 1
2.10.2-61 ..... Revision 1
2.10.2-62 ..... Revision 1
2.10.2-63 ..... Revision 1
2.10.2-64 ..... Revision 1
2.10.2-65 ..... Revision 1
2.10.2-66 ..... Revision 1
2.10.2-67 ..... Revision 1
2.10.2-68 ..... Revision 1
2.10.2-69 ..... Revision 1
2.10.2-70 ..... Revision 1
2.10.2-71 ..... Revision 1
2.10.2-72 ..... Revision 1
2.10.2-73 ..... Revision 1
2.10.2-74 ..... Revision 1
2.10.2-75 ..... Revision 1
2.10.2-76 ..... Revision 2

List of Effective Pages (Continued)

2.10.2-77 ..... Revision 1
2.10.2-78 ..... Revision 1
2.10.2-79 ..... Revision 1
2.10.2-80 ..... Revision 1
2.10.2-81 ..... Revision 1
2.10.2-82 ..... Revision 1
2.10.2-83 ..... Revision 1
2.10.2-84 ..... Revision 1
2.10.2-85 ..... Revision 1
2.10.2-86 ..... Revision 1
2.10.2-87 ..... Revision 1
2.10.2-88 ..... Revision 1
2.10.2-89 ..... Revision 1
2.10.2-90 ..... Revision 1
2.10.2-91 ..... Revision 1
2.10.2-92 ..... Revision 1
2.10.2-93 ..... Revision 1
2.10.2-94 ..... Revision 1
2.10.3-1 .....Revision STC-02A
2.10.3-2 .....Revision STC-02A
2.10.3-3 .....Revision STC-02A
2.10.3-4 .....Revision STC-02A
2.10.3-5 .....Revision STC-02A
2.10.3-6 .....Revision STC-02A
2.10.3-7 .....Revision STC-02A
2.10.3-8 .....Revision STC-02A
2.10.4-1 .....Revision STC-00A
2.10.4-2 ..... Revision 1
2.10.4-3 ..... Revision 1
2.10.4-4 ..... Revision 1
2.10.4-5 ..... Revision 1
2.10.4-6. ..... Revision 1
2.10.4-7. ..... Revision 1
2.10.4-8. ..... Revision 1
2.10.4-9 ..... Revision 1
2.10.4-10 ..... Revision 1
2.10.4-11 ..... Revision 1
2.10.4-12 ..... Revision 1
2.10.4-13 ..... Revision 1
2.10.4-14 ..... Revision 1
2.10.4-15 ..... Revision 1
2.10.4-16 ..... Revision 1
2.10.4-17 ..... Revision 1
2.10.4-18 ..... Revision 1
2.10.4-19 ..... Revision 1
2.10.4-20 ..... Revision 1
2.10.4-21 ..... Revision 1
2.10.4-22 ..... Revision 1
2.10.4-23 ..... Revision 1
2.10.4-24 ..... Revision 1
2.10.4-25 ..... Revision 1
2.10.4-26 ..... Revision 1
2.10.4-27 ..... Revision 1
2.10.4-28 ..... Revision 1
2.10.4-29 ..... Revision 1
2.10.4-30 ..... Revision 1
2.10.4-31 ..... Revision 1
2.10.4-32 ..... Revision 1
2.10.4-33 ..... Revision 1
2.10.4-34 ..... Revision 1
2.10.4-35 ..... Revision 1
2.10.4-36 ..... Revision 1
2.10.4-37 ..... Revision 1
2.10.4-38 ..... Revision 1
2.10.4-39 ..... Revision 1
2.10.4-40 ..... Revision 1
2.10.4-41 ..... Revision 1
2.10.4-42 ..... Revision 1
2.10.4-43 ..... Revision 1
2.10.4-44 .....Revision STC-00A

List of Effective Pages (Continued)

2.10.4-45 .....Revision STC-00A
2.10.4-46 .....Revision STC-00A
2.10.4-47 .....Revision STC-00A
2.10.4-48 .....Revision STC-00A
2.10.4-49 .....Revision STC-00A
2.10.4-50 ..... Revision 1
2.10.4-51 ..... Revision 1
2.10.4-52 ..... Revision 1
2.10.4-53 ..... Revision 1
2.10.4-54 ..... Revision 1
2.10.4-55 ..... Revision 1
2.10.4-56 ..... Revision 1
2.10.4-57 ..... Revision 1
2.10.4-58 ..... Revision 1
2.10.4-59 ..... Revision 1
2.10.4-60 ..... Revision 1
2.10.4-61 ..... Revision 1
2.10.4-62 ..... Revision 1
2.10.4-63 ..... Revision 1
2.10.4-64 ..... Revision 1
2.10.4-65 ..... Revision 1
2.10.4-66 ..... Revision 1
2.10.4-67 ..... Revision 1
2.10.4-68 ..... Revision 1
2.10.4-69 ..... Revision 1
2.10.4-70 ..... Revision 1
2.10.4-71 ..... Revision 1
2.10.4-72 ..... Revision 1
2.10.4-73 ..... Revision 1
2.10.4-74 ..... Revision 1
2.10.4-75 ..... Revision 1
2.10.4-76 ..... Revision 1
2.10.4-77 ..... Revision 1
2.10.4-78 ..... Revision 1
2.10.4-79 ..... Revision 1
2.10.4-80 ..... Revision 1
2.10.4-81 ..... Revision 1
2.10.4-82 ..... Revision 10
2.10.4-83 ..... Revision 1
2.10.4-84 ..... Revision 1
2.10.4-85 ..... Revision 2
2.10.4-86 ..... Revision 2
2.10.4-87 ..... Revision 2
2.10.4-88 ..... Revision 1
2.10.4-89 ..... Revision 1
2.10.4-90 ..... Revision 1
2.10.4-91 ..... Revision 1
2.10.4-92 ..... Revision 1
2.10.4-93 ..... Revision 1
2.10.4-94 ..... Revision 1
2.10.4-95 ..... Revision 1
2.10.4-96 ..... Revision 1
2.10.4-97 ..... Revision 2
2.10.4-98 ..... Revision 2
2.10.4-99 ..... Revision 2
2.10.4-100 ..... Revision 1
2.10.4-101 ..... Revision 1
2.10.4-102 ..... Revision 1
2.10.4-103 ..... Revision 1
2.10.4-104 ..... Revision 1
2.10.4-105 ..... Revision 1
2.10.4-106 ..... Revision 1
2.10.4-107 ..... Revision 1
2.10.4-108 ..... Revision 1
2.10.4-109 ..... Revision 1
2.10.4-110 ..... Revision 1
2.10.4-111 ..... Revision 2
2.10.4-112 ..... Revision 2
2.10.4-113 ..... Revision 2
2.10.4-114 ..... Revision 2

List of Effective Pages (Continued)

2.10.4-115 ..... Revision 2
2.10.4-116 ..... Revision 2
2.10.4-117 ..... Revision 2
2.10.4-118 ..... Revision 2
2.10.4-119 ..... Revision 2
2.10.4-120 ..... Revision 1
2.10.4-121 ..... Revision 1
2.10.4-122 ..... Revision 1
2.10.4-123 ..... Revision 1
2.10.4-124 ..... Revision 1
2.10.4-125 ..... Revision 1
2.10.4-126 ..... Revision 1
2.10.4-127 ..... Revision 1
2.10.4-128 ..... Revision 1
2.10.4-129 ..... Revision 1
2.10.4-130 ..... Revision 1
2.10.4-131 ..... Revision 2
2.10.4-132 ..... Revision 2
2.10.4-133 ..... Revision 2
2.10.4-134 ..... Revision 2
2.10.4-135 ..... Revision 2
2.10.4-136 ..... Revision 2
2.10.4-137 ..... Revision 2
2.10.4-138 ..... Revision 2
2.10.4-139 ..... Revision 2
2.10.4-140 ..... Revision 1
2.10.4-141 ..... Revision 1
2.10.4-142 ..... Revision 2
2.10.4-143 ..... Revision 1
2.10.4-144 ..... Revision 1
2.10.4-145 ..... Revision 1
2.10.4-146 ..... Revision 1
2.10.4-147 ..... Revision 1
2.10.4-148 ..... Revision 1
2.10.4-149 ..... Revision 2
2.10.4-150 ..... Revision 2
2.10.4-151 ..... Revision 2
2.10.4-152 ..... Revision 1
2.10.4-153 ..... Revision 1
2.10.4-154 ..... Revision 1
2.10.4-155 ..... Revision 1
2.10.4-156 ..... Revision 1
2.10.4-157 ..... Revision 1
2.10.4-158 ..... Revision 10
2.10.4-159 ..... Revision 1
2.10.4-160 ..... Revision 1
2.10.4-161 ..... Revision 1
2.10.4-162 ..... Revision 1
2.10.4-163 ..... Revision 1
2.10.4-164 ..... Revision 1
2.10.4-165 ..... Revision 1
2.10.4-166 ..... Revision 1
2.10.4-167 ..... Revision 1
2.10.4-168 ..... Revision 1
2.10.4-169 ..... Revision 1
2.10.4-170 ..... Revision 1
2.10.4-171 ..... Revision 1
2.10.4-172 ..... Revision 2
2.10.4-173 ..... Revision 2
2.10.4-174 ..... Revision 2
2.10.4-175 ..... Revision 1
2.10.4-176 ..... Revision 1
2.10.4-177 ..... Revision 1
2.10.4-178 ..... Revision 1
2.10.4-179 ..... Revision 1
2.10.4-180 ..... Revision 1
2.10.4-181 ..... Revision 1
2.10.4-182 ..... Revision 1
2.10.4-183 ..... Revision 1
2.10.4-184 ..... Revision 1

List of Effective Pages (Continued)

2.10.4-185 ..... Revision 10
2.10.4-186 ..... Revision 1
2.10.4-187 ..... Revision 1
2.10.4-188 ..... Revision 1
2.10.4-189 ..... Revision 1
2.10.4-190 ..... Revision 2
2.10.4-191 ..... Revision 2
2.10.4-192 ..... Revision 2
2.10.4-193 ..... Revision 1
2.10.4-194 ..... Revision 1
2.10.4-195 ..... Revision 1
2.10.4-196 ..... Revision 1
2.10.4-197 ..... Revision 1
2.10.4-198 ..... Revision 1
2.10.4-199 ..... Revision 1
2.10.4-200 ..... Revision 1
2.10.4-201 ..... Revision 1
2.10.4-202 ..... Revision 1
2.10.4-203 ..... Revision 1
2.10.4-204 ..... Revision 1
2.10.4-205 ..... Revision 2
2.10.4-206 ..... Revision 2
2.10.4-207 ..... Revision 2
2.10.4-208 ..... Revision 2
2.10.4-209 ..... Revision 2
2.10.4-210 ..... Revision 2
2.10.4-211 ..... Revision 1
2.10.4-212 ..... Revision 1
2.10.4-213 ..... Revision 1
2.10.4-214 ..... Revision 1
2.10.4-215 ..... Revision 1
2.10.4-216 ..... Revision 1
2.10.4-217 ..... Revision 2
2.10.4-218 ..... Revision 2
2.10.4-219 ..... Revision 2
2.10.4-220 ..... Revision 2
2.10.4-221 ..... Revision 2
2.10.4-222 ..... Revision 2
2.10.4-223 ..... Revision 1
2.10.4-224 ..... Revision 1
2.10.4-225 ..... Revision 1
2.10.4-226 ..... Revision 1
2.10.4-227 ..... Revision 1
2.10.4-228 ..... Revision 2
2.10.4-229 ..... Revision 2
2.10.4-230 ..... Revision 1
2.10.4-231 ..... Revision 1
2.10.4-232 ..... Revision 1
2.10.4-233 ..... Revision 1
2.10.4-234 ..... Revision 1
2.10.4-235 ..... Revision 1
2.10.4-236 ..... Revision 1
2.10.4-237 ..... Revision 1
2.10.4-238 ..... Revision 1
2.10.4-239 ..... Revision 1
2.10.4-240 ..... Revision 1
2.10.4-241 ..... Revision 2
2.10.4-242 ..... Revision 2
2.10.4-243 ..... Revision 1
2.10.4-244 ..... Revision 1
2.10.4-245 ..... Revision 1
2.10.4-246 ..... Revision 1
2.10.4-247 ..... Revision 1
2.10.4-248 ..... Revision 1
2.10.4-249 ..... Revision 1
2.10.4-250 ..... Revision 1
2.10.4-251 ..... Revision 1
2.10.4-252 ..... Revision 1
2.10.4-253 ..... Revision 1
2.10.4-254 ..... Revision 2

List of Effective Pages (Continued)

2.10.4-255 ..... Revision 2
2.10.4-256 ..... Revision 2
2.10.4-257 ..... Revision 1
2.10.4-258 ..... Revision 10
2.10.4-259 ..... Revision 1
2.10.4-260 ..... Revision 1
2.10.4-261 ..... Revision 2
2.10.4-262 ..... Revision 1
2.10.4-263 ..... Revision 1
2.10.4-264 ..... Revision 1
2.10.4-265 ..... Revision 1
2.10.4-266 ..... Revision 1
2.10.4-267 ..... Revision 2
2.10.4-268 ..... Revision 2
2.10.4-269 ..... Revision 1
2.10.4-270 ..... Revision 1
2.10.4-271 ..... Revision 1
2.10.4-272 ..... Revision 1
2.10.4-273 ..... Revision 1
2.10.4-274 ..... Revision 2
2.10.4-275 ..... Revision 2
2.10.4-276 ..... Revision 1
2.10.4-277 ..... Revision 1
2.10.4-278 ..... Revision 1
2.10.4-279 ..... Revision 1
2.10.4-280 ..... Revision 1
2.10.4-281 ..... Revision 2
2.10.4-282 ..... Revision 2
2.10.4-283 ..... Revision 1
2.10.4-284 ..... Revision 1
2.10.4-285 ..... Revision 1
2.10.4-286 ..... Revision 1
2.10.4-287 ..... Revision 1
2.10.4-288 ..... Revision 1
2.10.5-1 ..... Revision 10
2.10.5-2 ..... Revision STC-00A
2.10.5-3 ..... Revision STC-00A
2.10.5-4 ..... Revision 1
2.10.5-5 ..... Revision 1
2.10.5-6 ..... Revision 1
2.10.5-7 ..... Revision 10
2.10.5-8 ..... Revision 10
2.10.5-9 ..... Revision STC-00A
2.10.5-10 ..... Revision 10
2.10.5-11 ..... Revision 10
2.10.5-12 ..... Revision 10
2.10.5-13 ..... Revision 10
2.10.5-14 ..... Revision STC-00A
2.10.5-15 ..... Revision STC-00A
2.10.5-16 ..... Revision STC-00A
2.10.5-17 ..... Revision STC-00A
2.10.5-18 ..... Revision STC-00A
2.10.5-19 ..... Revision STC-00A
2.10.5-20 ..... Revision STC-00A
2.10.5-21 ..... Revision STC-00A
2.10.5-22 ..... Revision STC-00A
2.10.6-1 ..... Revision STC-00A
2.10.6-2 ..... Revision STC-00A
2.10.6-3 ..... Revision STC-00A
2.10.6-4 ..... Revision STC-00A
2.10.6-5 ..... Revision STC-00A
2.10.6-6 ..... Revision STC-00A
2.10.6-7 ..... Revision 2
2.10.6-8 ..... Revision 2
2.10.6-9 ..... Revision STC-00A
2.10.6-10 ..... Revision STC-00A
2.10.6-11 ..... Revision STC-00A
2.10.6-12 ..... Revision STC-00A
2.10.6-13 ..... Revision 2
2.10.6-14 ..... Revision STC-00A

List of Effective Pages (Continued)

2.10.6-15 .....Revision STC-00A
2.10.6-16 .....Revision STC-00A
2.10.6-17 .....Revision STC-00A
2.10.6-18 .....Revision STC-00A
2.10.6-19 .....Revision STC-00A
2.10.6-20 ..... Revision 2
2.10.6-21 ..... Revision 2
2.10.6-22 ..... Revision 2
2.10.6-23 ..... Revision 2
2.10.6-24 ..... Revision 2
2.10.6-25 ..... Revision 2
2.10.6-26 ..... Revision 2
2.10.6-27 ..... Revision 2
2.10.6-28 ..... Revision 2
2.10.6-29 ..... Revision 2
2.10.6-30 ..... Revision 2
2.10.6-31 ..... Revision 2
2.10.6-32 ..... Revision 2
2.10.6-33 ..... Revision 2
2.10.6-34 ..... Revision 2
2.10.6-35 ..... Revision 2
2.10.6-36 ..... Revision 2
2.10.6-37 ..... Revision 2
2.10.6-38 ..... Revision 2
2.10.6-39 ..... Revision 2
2.10.6-40 ..... Revision 2
2.10.6-41 ..... Revision 2
2.10.6-42 ..... Revision 2

13 drawings in Sections
2.10.6.6 and 2.10.6.7

2.10.6-43 ..... Revision 2
2.10.6-44 ..... Revision 2
2.10.6-45 ..... Revision 2
2.10.6-46 ..... Revision 2
2.10.6-47 ..... Revision 2
2.10.6-48 ..... Revision 2
2.10.6-49 ..... Revision 2
2.10.6-50 ..... Revision 2
2.10.6-51 ..... Revision 2
2.10.6-52 ..... Revision 2
2.10.6-53 ..... Revision 2
2.10.6-54 ..... Revision 2
2.10.6-55 ..... Revision 2
2.10.6-56 ..... Revision 2
2.10.6-57 ..... Revision 2
2.10.6-58 ..... Revision 2
2.10.6-59 ..... Revision 2
2.10.6-60 ..... Revision 2
2.10.6-61 ..... Revision 2
2.10.6-62 ..... Revision 2
2.10.6-63 ..... Revision 2
2.10.6-64 ..... Revision 2
2.10.6-65 ..... Revision 2
2.10.6-66 ..... Revision 2
2.10.6-67 ..... Revision 2
2.10.6-68 ..... Revision 2
2.10.6-69 ..... Revision 2
2.10.6-70 ..... Revision 2
2.10.6-71 ..... Revision 2
2.10.6-72 ..... Revision 2
2.10.6-73 ..... Revision 2
2.10.6-74 ..... Revision 2
2.10.6-75 ..... Revision 2
2.10.6-76 ..... Revision 2
2.10.6-77 ..... Revision 2
2.10.6-78 ..... Revision 2
2.10.6-79 ..... Revision 2
2.10.6-80 ..... Revision 2

List of Effective Pages (Continued)

2.10.6-81 ..... Revision 2
2.10.6-82 ..... Revision 2
2.10.6-83 ..... Revision 2
2.10.6-84 ..... Revision 2
2.10.6-85 ..... Revision 2
2.10.6-86 ..... Revision 2
2.10.6-87 ..... Revision 2
2.10.6-88 ..... Revision 2
2.10.6-89 ..... Revision 2
2.10.6-90 ..... Revision 2
2.10.6-91 ..... Revision 2
2.10.6-92 ..... Revision 2
2.10.6-93 ..... Revision 2
2.10.6-94 ..... Revision 2
2.10.7-1 .....Revision STC-00A
2.10.7-2 .....Revision STC-00A
2.10.7-3 .....Revision STC-00A
2.10.7-4 .....Revision STC-00A
2.10.7-5 .....Revision STC-00A
2.10.7-6 .....Revision STC-00A
2.10.7-7 .....Revision STC-00A
2.10.7-8 .....Revision STC-00A
2.10.7-9 .....Revision STC-00A
2.10.7-10 .....Revision STC-00A
2.10.7-11 .....Revision STC-00A
2.10.7-12 .....Revision STC-00A
2.10.7-13 .....Revision STC-00A
2.10.7-14 .....Revision STC-00A
2.10.7-15 .....Revision STC-00A
2.10.7-16 .....Revision STC-00A
2.10.7-17 .....Revision STC-00A
2.10.7-18 .....Revision STC-00A
2.10.7-19 .....Revision STC-00A
2.10.7-20 .....Revision STC-00A
2.10.7-21 .....Revision STC-00A
2.10.7-22 .....Revision STC-00A
2.10.7-23 .....Revision STC-00A
2.10.7-24 .....Revision STC-00A
2.10.7-25 .....Revision STC-00A
2.10.7-26 .....Revision STC-00A
2.10.8-1 .....Revision STC-01B
2.10.8-2 .....Revision STC-01B
2.10.8-3 .....Revision STC-01B
2.10.8-4 .....Revision STC-01B
2.10.8-5 .....Revision STC-01B
2.10.8-6 .....Revision STC-01B
2.10.8-7 .....Revision STC-01B
2.10.8-8 .....Revision STC-01B
2.10.8-9 .....Revision STC-01B
2.10.8-10 .....Revision STC-01B
2.10.8-11 .....Revision STC-01B
2.10.8-12 .....Revision STC-01B
2.10.8-13 .....Revision STC-01B
2.10.8-14 .....Revision STC-01B
2.10.8-15 .....Revision STC-01B
2.10.8-16 .....Revision STC-01B
2.10.8-17 .....Revision STC-01B
2.10.8-18 .....Revision STC-01B
2.10.8-19 .....Revision STC-01B
2.10.8-20 .....Revision STC-01B
2.10.8-21 .....Revision STC-01B
2.10.8-22 .....Revision STC-01B
2.10.8-23 .....Revision STC-01B
2.10.9-1 ..... Revision 10
2.10.9-2 ..... Revision 2
2.10.9-3 ..... Revision 1
2.10.9-4 ..... Revision 1
2.10.9-5 ..... Revision 1
2.10.9-6 ..... Revision 1
2.10.9-7 ..... Revision 1

List of Effective Pages (Continued)

2.10.9-8 ..... Revision 1
2.10.9-9 ..... Revision 1
2.10.9-10 ..... Revision 1
2.10.9-11 ..... Revision 1
2.10.9-12 ..... Revision 1
2.10.10-1 ..... Revision 10
2.10.10-2 .....Revision STC-00A
2.10.10-3 .....Revision STC-00A
2.10.10-4 ..... Revision 2
2.10.10-5 ..... Revision 2
2.10.10-6 ..... Revision 2
2.10.10-7 ..... Revision 2
2.10.10-8 ..... Revision 2
2.10.10-9 ..... Revision 2
2.10.10-10 ..... Revision 10
2.10.10-11 .....Revision STC-00A
2.10.11-1 .....Revision STC-00A
2.10.11-2 ..... Revision 10
2.10.11-3 ..... Revision 10
2.10.11-4 ..... Revision 10
2.10.11-5 .....Revision STC-00A
2.10.11-6 .....Revision STC-00A
2.10.11-7 .....Revision STC-00A
2.10.11-8 .....Revision STC-00A
2.10.12-1 .....Revision STC-01B
2.10.12-2 .....Revision STC-01B
2.10.12-3 .....Revision STC-01B
2.10.12-4 .....Revision STC-01B
2.10.12-5 .....Revision STC-01B
2.10.12-6 .....Revision STC-01B
2.10.12-7 .....Revision STC-01B
2.10.12-8 .....Revision STC-01B
2.10.12-9 .....Revision STC-01B
2.10.12-10 .....Revision STC-01B
2.10.12-11 .....Revision STC-01B
2.10.12-12 .....Revision STC-01B
2.10.12-13 .....Revision STC-01B
2.10.12-14 .....Revision STC-01B
2.10.12-15 .....Revision STC-01B
2.10.12-16 .....Revision STC-01B
2.10.12-17 .....Revision STC-01B
2.10.12-18 .....Revision STC-01B
2.10.12-19 .....Revision STC-01B
2.10.12-20 .....Revision STC-01B
2.10.12-21 .....Revision STC-01B
2.10.12-22 .....Revision STC-01B
2.10.12-23 .....Revision STC-01B
2.10.12-24 .....Revision STC-01B
2.10.12-25 .....Revision STC-01B
2.10.12-26 .....Revision STC-01B
2.10.12-27 .....Revision STC-01B
2.10.12-28 .....Revision STC-01B
2.10.12-29 .....Revision STC-01B
2.10.12-30 .....Revision STC-01B
2.10.12-31 .....Revision STC-01B

4 drawings in Section 2.10.12

Chapter 3

3-i .....Revision STC-01B
3-ii .....Revision STC-00A
3-iii .....Revision STC-01B
3-iv .....Revision STC-01B
3-v .....Revision STC-01B
3-vi .....Revision STC-01B
3.1-1 .....Revision STC-00A
3.1-2 .....Revision STC-00A
3.1-3 .....Revision STC-00A
3.1-4 .....Revision STC-00A

List of Effective Pages (Continued)

3.1-5 .....Revision STC-01B
3.1-6 .....Revision STC-00A
3.1-7 .....Revision STC-00A
3.1-8 .....Revision STC-00A
3.1-9 .....Revision STC-00A
3.1-10 .....Revision STC-00A
3.1-11 .....Revision STC-00A
3.2-1 ..... Revision 10
3.2-2 ..... Revision 10
3.2-3 ..... Revision 10
3.2-4 .....Revision STC-00A
3.2-5 .....Revision STC-00A
3.2-6 .....Revision STC-00A
3.2-7 .....Revision STC-00A
3.2-8 .....Revision STC-00A
3.2-9 .....Revision STC-00A
3.2-10 .....Revision STC-00A
3.2-11 .....Revision STC-00A
3.2-12 .....Revision STC-00A
3.2-13 .....Revision STC-00A
3.2-14 .....Revision STC-00A
3.3-1 ..... Revision 10
3.3-2 ..... Revision 10
3.3-3 .....Revision STC-00A
3.3-4 .....Revision STC-00A
3.3-5 ..... Revision 10
3.3-6 .....Revision STC-00A
3.4-1 ..... Revision 10
3.4-2 ..... Revision 10
3.4-3 .....Revision STC-00A
3.4-4 ..... Revision 10
3.4-5 .....Revision STC-00A
3.4-6 .....Revision STC-00A
3.4-7 .....Revision STC-00A
3.4-8 .....Revision STC-00A
3.4-9 .....Revision STC-00A
3.4-10 .....Revision STC-00A
3.4-11 .....Revision STC-00A
3.4-12 .....Revision STC-00A
3.4-13 .....Revision STC-00A
3.4-14 .....Revision STC-00A
3.4-15 .....Revision STC-00A
3.4-16 .....Revision STC-00A
3.4-17 .....Revision STC-00A
3.4-18 .....Revision STC-00A
3.4-19 .....Revision STC-01B
3.4-20 .....Revision STC-01B
3.4-21 .....Revision STC-00A
3.4-22 .....Revision STC-00A
3.4-23 .....Revision STC-00A
3.4-24 .....Revision STC-01B
3.4-25 .....Revision STC-01B
3.4-26 .....Revision STC-01B
3.4-27 .....Revision STC-01B
3.4-28 .....Revision STC-01B
3.4-29 .....Revision STC-01B
3.4-30 .....Revision STC-01B
3.4-31 .....Revision STC-01B
3.4-32 .....Revision STC-01B
3.4-33 .....Revision STC-01B
3.4-34 .....Revision STC-01B
3.4-35 .....Revision STC-01B
3.4-36 .....Revision STC-01B
3.4-37 .....Revision STC-01B
3.4-38 .....Revision STC-01B
3.4-39 .....Revision STC-01B
3.4-40 .....Revision STC-01B
3.4-41 .....Revision STC-01B
3.4-42 .....Revision STC-01B
3.4-43 .....Revision STC-01B

List of Effective Pages (Continued)

3.4-44 .....Revision STC-01B
3.4-45 .....Revision STC-01B
3.4-46 .....Revision STC-01B
3.4-47 .....Revision STC-01B
3.4-48 .....Revision STC-01B
3.4-49 .....Revision STC-01B
3.4-50 .....Revision STC-01B
3.4-51 .....Revision STC-01B
3.4-52 .....Revision STC-01B
3.4-53 .....Revision STC-01B
3.4-54 .....Revision STC-01B
3.4-55 .....Revision STC-01B
3.4-56 .....Revision STC-01B
3.4-57 .....Revision STC-01B
3.4-58 .....Revision STC-01B
3.4-59 .....Revision STC-01B
3.4-60 .....Revision STC-01B
3.4-61 .....Revision STC-01B
3.4-62 .....Revision STC-01B
3.4-63 .....Revision STC-01B
3.4-64 .....Revision STC-01B
3.4-65 .....Revision STC-01B
3.4-66 .....Revision STC-01B
3.4-67 .....Revision STC-01B
3.4-68 .....Revision STC-01B
3.4-69 .....Revision STC-01B
3.4-70 .....Revision STC-01B
3.4-71 .....Revision STC-01B
3.4-72 .....Revision STC-01B
3.4-73 .....Revision STC-01B
3.4-74 .....Revision STC-01B
3.4-75 .....Revision STC-01B
3.4-76 .....Revision STC-01B
3.4-77 .....Revision STC-01B
3.4-78 .....Revision STC-01B
3.4-79 .....Revision STC-01B
3.4-80 .....Revision STC-01B
3.4-81 .....Revision STC-01B
3.4-82 .....Revision STC-01B
3.4-83 .....Revision STC-01B
3.4-84 .....Revision STC-01B
3.4-85 .....Revision STC-01B
3.4-86 .....Revision STC-01B
3.4-87 .....Revision STC-01B
3.4-88 .....Revision STC-01B
3.4-89 .....Revision STC-01B
3.5-1 .....Revision STC-00A
3.5-2 .....Revision STC-00A
3.5-3 .....Revision STC-00A
3.5-4 .....Revision STC-00A
3.5-5 .....Revision STC-00A
3.5-6 .....Revision STC-00A
3.5-7 .....Revision STC-00A
3.5-8 .....Revision STC-00A
3.5-9 .....Revision STC-00A
3.5-10 .....Revision STC-00A
3.5-11 .....Revision STC-00A
3.5-12 .....Revision STC-00A
3.5-13 .....Revision STC-00A
3.5-14 .....Revision STC-00A
3.5-15 .....Revision STC-00A
3.5-16 .....Revision STC-00A

Chapter 4

4-i .....Revision STC-00A
4-ii .....Revision STC-00A
4.1-1 .....Revision STC-00A
4.1-2 .....Revision STC-00A
4.1-3 .....Revision STC-00A

List of Effective Pages (Continued)

4.1-4 .....Revision STC-00A
4.1-5 .....Revision STC-00A
4.1-6 .....Revision STC-02A
4.1-7 .....Revision STC-02A
4.1-8 .....Revision STC-02A
4.1-9 .....Revision STC-00A
4.1-10 .....Revision STC-00A
4.1-11 .....Revision STC-00A
4.2-1 .....Revision STC-00A
4.2-2 .....Revision STC-00A
4.2-3 .....Revision STC-00A
4.2-4 .....Revision STC-00A
4.2-5 .....Revision STC-00A
4.3-1 .....Revision STC-00A
4.3-2 ..... Revision 10
4.4-1 .....Revision STC-00A
4.5-1 ..... Revision 1
4.5-2 ..... Revision 1
4.5-3 ..... Revision 1
4.5-4 ..... Revision 1
4.5-5 ..... Revision 1
4.5-6 ..... Revision 1
4.5-7 ..... Revision 1
4.5-8 ..... Revision 1
4.5-9 ..... Revision 1
4.5-10 ..... Revision 1
4.5-11 ..... Revision 1
4.5-12 ..... Revision 1
4.5-13 ..... Revision 1
4.5-14 ..... Revision 1
4.5-15 ..... Revision 1
4.5-16 ..... Revision 1
4.5-17 ..... Revision 1
4.5-18 ..... Revision 1
4.5-19 ..... Revision 1
4.5-20 ..... Revision 1
4.5-21 ..... Revision 1
4.5-22 ..... Revision 1
4.5-23 ..... Revision 1

Chapter 5

5-i .....Revision STC-00A
5-ii .....Revision STC-01B
5-iii .....Revision STC-01B
5-iv .....Revision STC-01B
5-v .....Revision STC-01B
5-vi .....Revision STC-01B
5-1 .....Revision STC-01B
5-2 .....Revision STC-00A
5-3 .....Revision STC-00A
5-4 .....Revision STC-00A
5-5 .....Revision STC-00A
5-6 .....Revision STC-01B
5.1-1 .....Revision STC-00A
5.1-2 .....Revision STC-00A
5.1-3 .....Revision STC-00A
5.1-4 .....Revision STC-00A
5.1-5 .....Revision STC-01B
5.1-6 .....Revision STC-00A
5.1-7 .....Revision STC-00A
5.1-8 .....Revision STC-00A
5.1-9 .....Revision STC-01B
5.1-10 .....Revision STC-00A
5.1-11 .....Revision STC-00A
5.1-12 .....Revision STC-00A
5.1-13 .....Revision STC-00A
5.1-14 .....Revision STC-00A
5.1-15 .....Revision STC-01B
5.1-16 .....Revision STC-01B

List of Effective Pages (Continued)

5.1-17 .....Revision STC-01B
5.1-18 .....Revision STC-01B
5.1-19 .....Revision STC-01B
5.1-20 .....Revision STC-01B
5.1-21 .....Revision STC-01B
5.1-22 .....Revision STC-01B
5.1-23 .....Revision STC-01B
5.1-24 .....Revision STC-01B
5.1-25 .....Revision STC-01B
5.1-26 .....Revision STC-01B
5.1-27 .....Revision STC-01B
5.1-28 .....Revision STC-01B
5.1-29 .....Revision STC-01B
5.1-30 .....Revision STC-01B
5.1-31 .....Revision STC-01B
5.1-32 .....Revision STC-01B
5.1-33 .....Revision STC-01B
5.2-1 .....Revision STC-00A
5.2-2 .....Revision STC-00A
5.2-3 .....Revision STC-00A
5.2-4 .....Revision STC-00A
5.2-5 .....Revision STC-00A
5.2-6 .....Revision STC-00A
5.2-7 .....Revision STC-00A
5.2-8 .....Revision STC-00A
5.2-9 .....Revision STC-02A
5.2-10 .....Revision STC-00A
5.2-11 .....Revision STC-00A
5.2-12 .....Revision STC-01B
5.2-13 .....Revision STC-01B
5.2-14 .....Revision STC-01B
5.2-15 .....Revision STC-01B
5.2-16 .....Revision STC-01B
5.2-17 .....Revision STC-01B
5.2-18 .....Revision STC-01B
5.2-19 .....Revision STC-01B
5.2-20 .....Revision STC-01B
5.2-21 .....Revision STC-01B
5.2-22 .....Revision STC-01B
5.2-23 .....Revision STC-01B
5.2-24 .....Revision STC-01B
5.2-25 .....Revision STC-01B
5.2-26 .....Revision STC-01B
5.2-27 .....Revision STC-01B
5.2-28 .....Revision STC-01B
5.2-29 .....Revision STC-01B
5.2-30 .....Revision STC-01B
5.2-31 .....Revision STC-01B
5.2-32 .....Revision STC-01B
5.2-33 .....Revision STC-01B
5.2-34 .....Revision STC-01B
5.2-35 .....Revision STC-01B
5.3-1 .....Revision STC-00A
5.3-2 .....Revision STC-00A
5.3-3 .....Revision STC-00A
5.3-4 .....Revision STC-00A
5.3-5 .....Revision STC-00A
5.3-6 .....Revision STC-00A
5.3-7 .....Revision STC-00A
5.3-8 .....Revision STC-00A
5.3-9 .....Revision STC-01B
5.3-10 .....Revision STC-00A
5.3-11 .....Revision STC-00A
5.3-12 .....Revision STC-00A
5.3-13 .....Revision STC-00A
5.3-14 .....Revision STC-00A
5.3-15 .....Revision STC-00A
5.3-16 .....Revision STC-00A
5.3-17 .....Revision STC-00A
5.3-18 .....Revision STC-00A

List of Effective Pages (Continued)

5.3-19 .....Revision STC-00A
5.3-20 .....Revision STC-00A
5.3-21 .....Revision STC-00A
5.3-22 .....Revision STC-00A
5.3-23 .....Revision STC-00A
5.3-24 .....Revision STC-00A
5.3-25 .....Revision STC-00A
5.3-26 .....Revision STC-00A
5.3-27 .....Revision STC-01B
5.3-28 .....Revision STC-01B
5.3-29 .....Revision STC-00A
5.3-30 .....Revision STC-00A
5.3-31 .....Revision STC-00A
5.3-32 .....Revision STC-00A
5.3-33 .....Revision STC-00A
5.3-34 .....Revision STC-00A
5.3-35 .....Revision STC-00A
5.3-36 .....Revision STC-00A
5.3-37 .....Revision STC-01B
5.4-1 .....Revision STC-00A
5.4-2 .....Revision STC-00A
5.4-3 .....Revision STC-00A
5.4-4 .....Revision STC-00A
5.4-5 .....Revision STC-00A
5.4-6 .....Revision STC-01B
5.4-7 .....Revision STC-00A
5.4-8 .....Revision STC-00A
5.4-9 .....Revision STC-00A
5.4-10 .....Revision STC-00A
5.4-11 .....Revision STC-00A
5.4-12 .....Revision STC-00A
5.4-13 .....Revision STC-00A
5.4-14 .....Revision STC-00A
5.4-15 .....Revision STC-00A
5.4-16 .....Revision STC-00A
5.4-17 .....Revision STC-00A
5.4-18 .....Revision STC-00A
5.4-19 .....Revision STC-01B
5.4-20 .....Revision STC-01B
5.4-21 .....Revision STC-00A
5.4-22 .....Revision STC-00A
5.4-23 .....Revision STC-00A
5.4-24 .....Revision STC-00A
5.4-25 .....Revision STC-00A
5.4-26 .....Revision STC-00A
5.4-27 .....Revision STC-00A
5.4-28 .....Revision STC-00A
5.4-29 .....Revision STC-00A
5.4-30 .....Revision STC-00A
5.4-31 .....Revision STC-01B
5.4-32 .....Revision STC-01B

Chapter 6

6-i .....Revision STC-00A
6-ii .....Revision STC-00A
6-iii .....Revision STC-00A
6-iv .....Revision STC-00A
6-v .....Revision STC-00A
6.1-1 .....Revision STC-00A
6.1-2 .....Revision STC-00A
6.1-3 .....Revision STC-00A
6.1-4 .....Revision STC-01B
6.1-5 .....Revision STC-01B
6.2-1 .....Revision STC-00A
6.2-2 .....Revision STC-01B
6.2-3 .....Revision STC-00A
6.2-4 .....Revision STC-00A
6.2-5 .....Revision STC-00A
6.2-6 .....Revision STC-00A

List of Effective Pages (Continued)

6.2-7 .....Revision STC-00A
6.2-8 .....Revision STC-00A
6.2-9 .....Revision STC-00A
6.2-10 .....Revision STC-00A
6.3-1 .....Revision STC-00A
6.3-2 .....Revision STC-00A
6.3-3 .....Revision STC-00A
6.3-4 .....Revision STC-00A
6.3-5 ..... Revision 10
6.3-6 .....Revision STC-00A
6.3-7 .....Revision STC-01B
6.3-8 .....Revision STC-00A
6.4-1 .....Revision STC-00A
6.4-2 .....Revision STC-00A
6.4.1-1 .....Revision STC-00A
6.4.2-1 .....Revision STC-00A
6.4.2-2 .....Revision STC-00A
6.4.2-3 .....Revision STC-00A
6.4.2-4 .....Revision STC-00A
6.4.2-5 .....Revision STC-00A
6.4.2-6 .....Revision STC-00A
6.4.2-7 .....Revision STC-00A
6.4.3-1 .....Revision STC-00A
6.4.3-2 .....Revision STC-00A
6.4.3-3 .....Revision STC-00A
6.4.3-4 .....Revision STC-00A
6.4.3-5 .....Revision STC-00A
6.4.3-6 .....Revision STC-00A
6.4.3-7 .....Revision STC-00A
6.4.3-8 .....Revision STC-00A
6.4.4-1 .....Revision STC-00A
6.4.4-2 .....Revision STC-00A
6.4.4-3 .....Revision STC-00A
6.4.4-4 .....Revision STC-01B
6.4.4-5 .....Revision STC-01B
6.4.4-6 .....Revision STC-01B
6.4.4-7 .....Revision STC-00A
6.4.4-8 .....Revision STC-00A
6.4.4-9 .....Revision STC-00A
6.4.4-10 .....Revision STC-01B
6.4.4-11 .....Revision STC-01B
6.4.4-12 .....Revision STC-00A
6.4.4-13 .....Revision STC-00A
6.4.4-14 .....Revision STC-00A
6.4.4-15 .....Revision STC-00A
6.4.4-16 .....Revision STC-00A
6.4.4-17 .....Revision STC-00A
6.4.4-18 .....Revision STC-00A
6.4.4-19 .....Revision STC-00A
6.4.4-20 .....Revision STC-00A
6.4.4-21 .....Revision STC-00A
6.4.4-22 .....Revision STC-01B
6.4.4-23 .....Revision STC-01B
6.4.4-24 .....Revision STC-01B
6.4.4-25 .....Revision STC-01B
6.4.4-26 .....Revision STC-01B
6.4.4-27 .....Revision STC-01B
6.4.4-28 .....Revision STC-00A
6.4.4-29 .....Revision STC-00A
6.4.4-30 .....Revision STC-01B
6.5-1 .....Revision STC-00A
6.5-2 .....Revision STC-00A
6.5.1-1 .....Revision STC-00A
6.5.1-2 .....Revision STC-00A
6.5.1-3 .....Revision STC-00A
6.5.1-4 .....Revision STC-00A
6.5.1-5 .....Revision STC-00A
6.5.1-6 .....Revision STC-00A
6.5.1-7 .....Revision STC-00A
6.5.1-8 .....Revision STC-00A

List of Effective Pages (Continued)

6.5.1-9 .....Revision STC-00A
6.5.1-10 .....Revision STC-00A
6.5.1-11 .....Revision STC-00A
6.5.1-12 .....Revision STC-00A
6.5.1-13 .....Revision STC-00A
6.5.1-14 .....Revision STC-00A
6.5.1-15 .....Revision STC-00A
6.5.1-16 .....Revision STC-00A
6.5.1-17 .....Revision STC-00A
6.5.1-18 .....Revision STC-00A
6.5.1-19 .....Revision STC-00A
6.5.1-20 .....Revision STC-00A
6.5.1-21 .....Revision STC-00A
6.5.2-1 .....Revision STC-00A
6.5.2-2 .....Revision STC-00A
6.5.2-3 .....Revision STC-00A
6.5.2-4 .....Revision STC-00A
6.5.2-5 .....Revision STC-00A
6.5.2-6 .....Revision STC-00A
6.5.2-7 .....Revision STC-00A
6.5.2-8 .....Revision STC-00A
6.5.2-9 .....Revision STC-00A
6.5.2-10 .....Revision STC-00A
6.5.2-11 .....Revision STC-00A
6.5.2-12 .....Revision STC-00A
6.5.2-13 .....Revision STC-00A
6.5.2-14 .....Revision STC-00A
6.5.2-15 .....Revision STC-00A
6.5.2-16 .....Revision STC-00A
6.5.2-17 .....Revision STC-00A
6.5.2-18 .....Revision STC-00A
6.5.2-19 .....Revision STC-00A
6.5.2-20 .....Revision STC-00A
6.6-1 .....Revision STC-00A
6.6-2 .....Revision STC-00A
6.7-1 .....Revision STC-00A
6.7-2 .....Revision STC-00A
6.7-3 .....Revision STC-00A
6.7-4 .....Revision STC-00A
6.7-5 .....Revision STC-00A
6.7-6 .....Revision STC-00A
6.7-7 .....Revision STC-00A
6.7-8 .....Revision STC-00A
6.7-9 .....Revision STC-00A
6.7-10 .....Revision STC-00A
6.7-11 .....Revision STC-00A
6.7-12 .....Revision STC-00A
6.7-13 .....Revision STC-00A
6.7-14 .....Revision STC-00A
6.7-15 .....Revision STC-00A
6.7-16 .....Revision STC-00A
6.7-17 .....Revision STC-00A
6.7-18 .....Revision STC-00A
6.7-19 .....Revision STC-00A
6.7-20 .....Revision STC-00A
6.7-21 .....Revision STC-00A
6.7-22 .....Revision STC-00A
6.7-23 .....Revision STC-00A
6.7-24 .....Revision STC-00A
6.7-25 .....Revision STC-00A
6.7-26 .....Revision STC-00A
6.7-27 .....Revision STC-00A
6.7-28 .....Revision STC-00A
6.7-29 .....Revision STC-00A
6.7-30 .....Revision STC-00A
6.7-31 .....Revision STC-00A
6.7-32 .....Revision STC-00A
6.7-33 .....Revision STC-00A
6.7-34 .....Revision STC-00A
6.7-35 .....Revision STC-00A

List of Effective Pages (Continued)

6.7-36 .....Revision STC-00A
6.7-37 .....Revision STC-00A
6.7-38 .....Revision STC-00A
6.7-39 .....Revision STC-00A
6.7-40 .....Revision STC-00A
6.7-41 .....Revision STC-00A
6.7-42 .....Revision STC-00A
6.7-43 .....Revision STC-00A
6.7-44 .....Revision STC-00A
6.7-45 .....Revision STC-00A
6.7-46 .....Revision STC-00A
6.7-47 .....Revision STC-00A
6.7-48 .....Revision STC-00A
6.7-49 .....Revision STC-00A
6.7-50 .....Revision STC-00A
6.7-51 .....Revision STC-00A
6.7-52 .....Revision STC-00A
6.7-53 .....Revision STC-00A
6.7-54 .....Revision STC-00A
6.7-55 .....Revision STC-00A
6.7-56 .....Revision STC-00A
6.7-57 .....Revision STC-00A
6.7-58 .....Revision STC-00A
6.7-59 .....Revision STC-00A
6.7-60 .....Revision STC-00A
6.7-61 .....Revision STC-00A
6.7-62 .....Revision STC-00A
6.7-63 .....Revision STC-00A
6.7-64 .....Revision STC-00A
6.7-65 .....Revision STC-00A
6.7-66 .....Revision STC-00A
6.7-67 .....Revision STC-00A
6.7-68 .....Revision STC-00A
6.7-69 .....Revision STC-00A
6.7-70 .....Revision STC-00A
6.7-71 .....Revision STC-00A
6.7-72 .....Revision STC-00A
6.7-73 .....Revision STC-00A
6.7-74 .....Revision STC-00A
6.7-75 .....Revision STC-00A
6.7-76 .....Revision STC-00A
6.7-77 .....Revision STC-00A
6.7-78 .....Revision STC-00A
6.7-79 .....Revision STC-00A
6.7-80 .....Revision STC-00A
6.7-81 .....Revision STC-00A
6.7-82 .....Revision STC-00A
6.7-83 .....Revision STC-00A
6.7-84 .....Revision STC-00A
6.7-85 .....Revision STC-00A
6.7-86 .....Revision STC-00A
6.7-87 .....Revision STC-00A
6.7-88 .....Revision STC-00A
6.7-89 .....Revision STC-00A
6.7-90 .....Revision STC-00A
6.7-91 .....Revision STC-00A
6.7-92 .....Revision STC-00A
6.7-93 .....Revision STC-00A
6.7-94 .....Revision STC-00A
6.7-95 .....Revision STC-00A
6.7-96 .....Revision STC-00A
6.7-97 .....Revision STC-00A
6.7-98 .....Revision STC-00A
6.7-99 .....Revision STC-00A
6.7-100 .....Revision STC-00A
6.7-101 .....Revision STC-00A
6.7-102 .....Revision STC-00A
6.7-103 .....Revision STC-00A
6.7-104 .....Revision STC-00A
6.7-105 .....Revision STC-00A

List of Effective Pages (Continued)

6.7-106 .....Revision STC-00A
6.7-107 .....Revision STC-00A
6.7-108 .....Revision STC-00A
6.7-109 .....Revision STC-00A
6.7-110 .....Revision STC-00A
6.7-111 .....Revision STC-00A
6.7-112 .....Revision STC-00A
6.7-113 .....Revision STC-00A
6.7-114 .....Revision STC-00A
6.7-115 .....Revision STC-00A
6.7-116 .....Revision STC-00A
6.7-117 .....Revision STC-00A
6.7-118 .....Revision STC-00A
6.7-119 .....Revision STC-00A
6.7-120 .....Revision STC-00A
6.7-121 .....Revision STC-00A
6.7-122 .....Revision STC-00A
6.7-123 .....Revision STC-00A
6.7-124 .....Revision STC-00A
6.7-125 .....Revision STC-00A
6.7-126 .....Revision STC-00A
6.7-127 .....Revision STC-00A
6.7-128 .....Revision STC-00A
6.7-129 .....Revision STC-00A
6.7-130 .....Revision STC-00A
6.7-131 .....Revision STC-00A
6.7-132 .....Revision STC-00A
6.7-133 .....Revision STC-00A
6.7-134 .....Revision STC-00A
6.7-135 .....Revision STC-00A
6.7-136 .....Revision STC-00A
6.7-137 .....Revision STC-00A
6.7-138 .....Revision STC-00A
6.7-139 .....Revision STC-00A
6.7-140 .....Revision STC-00A
6.7-141 .....Revision STC-00A
6.7-142 .....Revision STC-00A
6.7-143 .....Revision STC-00A
6.7-144 .....Revision STC-00A
6.7-145 .....Revision STC-00A
6.7-146 .....Revision STC-00A
6.7-147 .....Revision STC-00A
6.7-148 .....Revision STC-00A
6.7-149 .....Revision STC-00A
6.7-150 .....Revision STC-00A
6.7-151 .....Revision STC-00A
6.7-152 .....Revision STC-00A
6.7-153 .....Revision STC-00A
6.7-154 .....Revision STC-00A
6.7-155 .....Revision STC-00A
6.7-156 .....Revision STC-00A
6.7-157 .....Revision STC-00A
6.7-158 .....Revision STC-00A
6.7-159 .....Revision STC-00A
6.7-160 .....Revision STC-00A
6.7-161 .....Revision STC-00A
6.7-162 .....Revision STC-00A
6.7-163 .....Revision STC-00A
6.7-164 .....Revision STC-00A
6.7-165 .....Revision STC-00A
6.7-166 .....Revision STC-00A
6.7-167 .....Revision STC-00A
6.7-168 .....Revision STC-00A
6.7-169 .....Revision STC-00A
6.7-170 .....Revision STC-00A
6.7-171 .....Revision STC-00A
6.7-172 .....Revision STC-00A
6.7-173 .....Revision STC-00A
6.7-174 .....Revision STC-00A
6.7-175 .....Revision STC-00A

List of Effective Pages (Continued)

6.7-176 .....Revision STC-00A
6.7-177 .....Revision STC-00A
6.7-178 .....Revision STC-00A
6.7-179 .....Revision STC-00A
6.7-180 .....Revision STC-00A
6.7-181 .....Revision STC-00A
6.7-182 .....Revision STC-00A
6.7-183 .....Revision STC-00A
6.7-184 .....Revision STC-00A
6.7-185 .....Revision STC-00A
6.7-186 .....Revision STC-00A
6.7-187 .....Revision STC-00A
6.7-188 .....Revision STC-00A
6.7-189 .....Revision STC-00A
6.7-190 .....Revision STC-00A
6.7-191 .....Revision STC-00A
6.7-192 .....Revision STC-00A
6.7-193 .....Revision STC-00A
6.7-194 .....Revision STC-00A
6.7-195 .....Revision STC-00A
6.7-196 .....Revision STC-00A
6.7-197 .....Revision STC-00A
6.7-198 .....Revision STC-00A
6.7-199 .....Revision STC-00A
6.7-200 .....Revision STC-00A
6.7-201 .....Revision STC-00A
6.7-202 .....Revision STC-00A
6.7-203 .....Revision STC-00A
6.7-204 .....Revision STC-00A
6.7-205 .....Revision STC-00A
6.7-206 .....Revision STC-00A
6.7-207 .....Revision STC-00A
6.7-208 .....Revision STC-00A
6.7-209 .....Revision STC-00A
6.7-210 .....Revision STC-00A
6.7-211 .....Revision STC-00A
6.7-212 .....Revision STC-00A
6.7-213 .....Revision STC-00A
6.7-214 .....Revision STC-00A
6.7-215 .....Revision STC-00A
6.7-216 .....Revision STC-00A
6.7-217 .....Revision STC-00A
6.7-218 .....Revision STC-00A
6.7-219 .....Revision STC-00A
6.7-220 .....Revision STC-00A
6.7-221 .....Revision STC-00A
6.7-222 .....Revision STC-00A
6.7-223 .....Revision STC-00A
6.7-224 .....Revision STC-00A
6.7-225 .....Revision STC-00A
6.7-226 .....Revision STC-00A
6.7-227 .....Revision STC-00A
6.7-228 .....Revision STC-00A
6.7-229 .....Revision STC-00A
6.7-230 .....Revision STC-00A
6.7-231 .....Revision STC-00A
6.7-232 .....Revision STC-00A
6.7-233 .....Revision STC-00A
6.7-234 .....Revision STC-00A
6.7-235 .....Revision STC-00A

Chapter 7

7-i .....Revision STC-01B
7-ii .....Revision STC-01B
7-1 .....Revision STC-01B
7-2 .....Revision STC-01B
7-3 .....Revision STC-01B
7.1-1 .....Revision STC-00A
7.1-2 .....Revision STC-01B

List of Effective Pages (Continued)

7.1-3 .....Revision STC-01B
7.1-4 .....Revision STC-01B
7.1-5 .....Revision STC-01B
7.1-6 .....Revision STC-00A
7.1-7 .....Revision STC-02A
7.1-8 .....Revision STC-02A
7.1-9 .....Revision STC-02A
7.1-10 .....Revision STC-02A
7.1-11 .....Revision STC-02A
7.2-1 .....Revision STC-01B
7.2-2 .....Revision STC-01B
7.2-3 .....Revision STC-01B
7.2-4 .....Revision STC-01B
7.2-5 .....Revision STC-01B
7.3-1 .....Revision STC-02A
7.3-2 ..... Revision 10
7.3-3 .....Revision STC-00A
7.3-4 .....Revision STC-01B
7.3-5 .....Revision STC-00A
7.3-6 .....Revision STC-01B
7.3-7 .....Revision STC-01B
7.3-8 .....Revision STC-01B
7.4-1 .....Revision STC-01B
7.4-2 .....Revision STC-01B
7.4-3 .....Revision STC-01B
7.5-1 .....Revision STC-01B

Chapter 8

8-i .....Revision STC-02A
8-ii .....Revision STC-01B
8-1 ..... Revision 10
8.1-1 .....Revision STC-00A
8.1-2 .....Revision STC-00A
8.1-3 .....Revision STC-00A
8.1-4 .....Revision STC-00A
8.1-5 .....Revision STC-00A
8.1-6 .....Revision STC-01B
8.1-7 .....Revision STC-02A
8.1-8 .....Revision STC-01B
8.1-9 .....Revision STC-01B
8.1-10 .....Revision STC-01B
8.1-11 .....Revision STC-00A
8.1-12 .....Revision STC-01B
8.1-13 .....Revision STC-01B
8.1-14 .....Revision STC-01B
8.1-15 .....Revision STC-02A
8.1-16 .....Revision STC-02A
8.1-17 .....Revision STC-02A
8.1-18 .....Revision STC-02A
8.2-1 .....Revision STC-00A
8.2-2 .....Revision STC-01B
8.2-3 .....Revision STC-01B
8.2-4 .....Revision STC-00A
8.2-5 .....Revision STC-00A
8.3-1 ..... Revision 10
8.4-1 .....Revision STC-00A
8.4-2 .....Revision STC-00A
8.4-3 .....Revision STC-00A
8.4-4 .....Revision STC-00A
8.4-5 .....Revision STC-00A
8.4-6 .....Revision STC-00A
8.4-7 ..... Revision 10
8.4-8 ..... Revision 10
8.4-9 ..... Revision 10

Chapter 9

9-i .....Revision STC-00A
9-1 .....Revision STC-00A

List of Effective Pages (Continued)

9-2 ..... Revision STC-00A
9-3 ..... Revision STC-00A
9-4 ..... Revision STC-00A
9-5 ..... Revision STC-00A
9-6 ..... Revision STC-00A
9-7 ..... Revision STC-00A
9-8 ..... Revision STC-00A
9-9 ..... Revision STC-00A
9-10 ..... Revision STC-00A
9-11 ..... Revision STC-00A
9-12 ..... Revision STC-00A
9-13 ..... Revision STC-00A

THIS PAGE INTENTIONALLY LEFT BLANK

Master Table of Contents (Continued)

2.6.16 CY-MPC Fuel Basket Analysis – Normal Conditions of Transport 2.6.16-1
2.6.16.1 Detailed Analysis of the CY-MPC Fuel Basket 2.6.16-7
2.6.16.2 CY-MPC Fuel Basket Finite Element Model Description 2.6.16-9
2.6.16.3 Thermal Expansion Evaluation of the CY-MPC Support Disk 2.6.16-20
2.6.16.4 Stress Evaluation of the CY-MPC Support Disk for a 1-Foot End Drop 2.6.16-23
2.6.16.5 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot End Drop Load Condition 2.6.16-26
2.6.16.6 Stress Evaluation of CY-MPC Tie Rods and Spacers for 1-Foot End Drop 2.6.16-29
2.6.16.7 Stress Evaluation of CY-MPC Support Disk for a 1-Foot Side Drop 2.6.16-32
2.6.16.8 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot Side Drop Load Condition 2.6.16-44
2.6.16.9 CY-MPC Support Disk Shear Stresses for 1-Foot Drop 2.6.16-51
2.6.16.10 Bearing Stress – Basket Contact with Canister Shell –CY-MPC 2.6.16-51
2.6.16.11 CY-MPC Fuel Basket Weldment Analysis for 1-Foot End Drop 2.6.16-52
2.6.16.12 CY-MPC Fuel Basket Support Disk – Buckling Evaluation 2.6.16-56
2.6.16.13 Stress Evaluation of the CY-MPC Support Disk for 1-Foot Oblique Drop 2.6.16-58
2.6.16.14 Stress Evaluation of the CY-MPC Support Disk for a Combined Thermal and 1-Foot Oblique Drop Load Condition 2.6.16-60
2.6.17 CY-MPC Reconfigured Fuel Assembly Analysis and Damaged Fuel Can Analysis – Normal Conditions of Transport 2.6.17-1
2.6.17.1 CY-MPC Reconfigured Fuel Assembly Evaluation 2.6.17-1
2.6.17.2 CY-MPC Damaged Fuel Can Evaluation 2.6.17-8

Master Table of Contents (Continued)

2.6.18 Spacer Design for Canistered Fuel – Normal Conditions of Transport 2.6.18-1
2.6.18.1 Spacer Evaluation for Yankee-MPC Canister Fuel and GTCC Waste 2.6.18-1
2.6.18.2 Spacer Evaluation for CY-MPC Canister Fuel and GTCC Waste 2.6.18-2
2.6.19 Greater Than Class C (GTCC) Basket Analysis – Normal Conditions of Transport 2.6.19-1
2.6.19.1 Yankee-MPC GTCC Basket Analysis 2.6.19-1
2.6.19.2 CY-MPC GTCC Basket Analysis 2.6.19-6

2.7 Hypothetical Accident Conditions 2.7-1
2.7.1 Free Drop (30 Feet) 2.7.1-1
2.7.1.1 Thirty-Foot End Drop 2.7.1.1-1
2.7.1.2 Thirty-Foot Side Drop 2.7.1.2-1
2.7.1.3 Thirty-Foot Corner Drop 2.7.1.3-1
2.7.1.4 Thirty-Foot Oblique Drop 2.7.1.4-1
2.7.1.5 Lead Slump Resulting From a Cask Drop Accident 2.7.1.5-1
2.7.1.6 Closure Analysis - Hypothetical Accident Conditions 2.7.1.6-1
2.7.2 Puncture 2.7.2-1
2.7.2.1 Puncture - Cask Side Midpoint 2.7.2.1-1
2.7.2.2 Puncture - Center of Outer Lid 2.7.2.2-1
2.7.2.3 Puncture - Center of Cask Bottom 2.7.2.3-1
2.7.2.4 Puncture - Port Cover 2.7.2.4-1
2.7.2.5 Puncture Accident - Shielding Consequences 2.7.2.5-1
2.7.2.6 Puncture - Conclusion 2.7.2.6-1
2.7.3 Thermal 2.7.3.1-1
2.7.3.1 Discussion 2.7.3.1-1
2.7.3.2 Pressure Stress Evaluation 2.7.3.2-1
2.7.3.3 Thermal Stress Evaluation 2.7.3.3-1
2.7.3.4 Bolts - Closure Lids (Thermal Accident) 2.7.3.4-1
2.7.3.5 Performance Summary - Thermal Accident 2.7.3.5-1
2.7.3.6 Conclusion 2.7.3.6-1
2.7.4 Crush 2.7.4-1
2.7.5 Immersion - Fissile Material 2.7.5-1

Master Table of Contents (Continued)

2.10.2 Finite Element Analysis 2.10.2-1
2.10.2.1 Model Descriptions 2.10.2-1
2.10.2.2 Loading Conditions 2.10.2-16
2.10.2.3 Finite Element Analysis Procedures 2.10.2-27
2.10.2.4 Finite Element Documentation Procedures 2.10.2-32
2.10.3 LS-DYNA Computer Code 2.10.3-1
2.10.3.1 Predicting Impact Deceleration using Strain Rate Sensitive Properties 2.10.3-1
2.10.3.2 Accounting for Strain Rate Sensitivity by Interpolation 2.10.3-2
2.10.4 Detailed Finite Element Stress Summaries - Directly Loaded Fuel Configuration 2.10.4-1
2.10.5 Inner Shell Buckling Analysis 2.10.5-1
2.10.5.1 Buckling Analysis 2.10.5-1
2.10.5.2 Analysis Results 2.10.5-2
2.10.5.3 Verification of the Code Case N-284 Buckling Evaluation of the NAC-STC Inner Shell and Transition Sections 2.10.5-3
2.10.5.4 Buckling Evaluation of the Inner Shell for the Yankee-MPC Fuel Configuration 2.10.5-9
2.10.5.5 Buckling Evaluation of the Inner Shell for the CY-MPC Fuel Configuration 2.10.5-14
2.10.6 Scale Model Test Program for the NAC-STC 2.10.6-1
2.10.6.1 Introduction 2.10.6-1
2.10.6.2 Purpose 2.10.6-2
2.10.6.3 Discussion 2.10.6-2
2.10.6.4 Eighth-Scale Redwood Impact Limiter Compression Tests 2.10.6-9
2.10.6.5 Quarter-Scale Model Drop Tests 2.10.6-14
2.10.6.6 NAC-STC Quarter-Scale Model Drawings 2.10.6-41
2.10.6.7 NAC-STC Eighth-Scale Model Drawings 2.10.6-42
2.10.7 Redwood Impact Limiter Force-Deflection Curves and Data – Directly Loaded Fuel Configuration 2.10.7-1
2.10.7.1 Potential Energy and Cask Drop Impact Motion 2.10.7-1
2.10.7.2 Conversion of Potential Energy to Kinetic Energy 2.10.7-9
2.10.7.3 Deceleration Forces and Energy Absorption Calculation 2.10.7-10
2.10.7.4 RBCUBED Calculated Force-Deflection Graphs 2.10.7-13

Master Table of Contents (Continued)

2.10.8 Bolts - Closure Lids (Stress Evaluations) 2.10.8-1
2.10.8.1 Analysis Approach 2.10.8-1
2.10.8.2 Inner Lid Closure Bolt Analyses 2.10.8-2
2.10.8.3 Outer Lid Closure Bolt Analyses 2.10.8-15
2.10.9 Lead Slump Evaluation 2.10.9-1
2.10.9.1 Methodology/Finite Element Analysis 2.10.9-2
2.10.9.2 Analysis Result 2.10.9-3
2.10.9.3 Conclusion 2.10.9-5
2.10.10 Assessment of the Effect of the Revised Temperature Distribution on Structural Qualification 2.10.10-1
2.10.10.1 Evaluation Methodology 2.10.10-1
2.10.10.2 Temperature Dependent Stress Results 2.10.10-3
2.10.10.3 Conclusions - Revised Temperature Distribution Evaluation 2.10.10-7
2.10.11 Sensitivity Studies of the Yankee-MPC Canistered Fuel Basket Analysis 2.10.11-1
2.10.11.1 Yankee-MPC Fuel Basket Drop Orientation 2.10.11-1
2.10.11.2 Gap Stiffness 2.10.11-2
2.10.11.3 Finite Element Mesh for the Support Disk Ligaments 2.10.11-3
2.10.12 Confirmatory Testing Program –Balsa Impact Limiters and Attachments 2.10.12-1
2.10.12.1 Confirmatory Testing Program Results Summary 2.10.12-1
2.10.12.2 Acceptance Criteria for Model Performance 2.10.12-3
2.10.12.3 Description of 30-Foot Drop Tests Performed at SNL 2.10.12-4
2.10.12.4 Results/Evaluation for the 30-Foot Side Drop Test 2.10.12-8
2.10.12.5 Results/Evaluation for the 30-Foot Top Corner Drop Test 2.10.12-10
2.10.12.6 Results/Evaluation for the 30-Foot Top End Drop Test 2.10.12-12
2.10.12.7 LS-DYNA Analyses of the NAC-STC Quarter-Scale Model 2.10.12-14

3.0 THERMAL EVALUATION 3.1-1

3.1 Discussion 3.1-1

Master Table of Contents (Continued)

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM 8-1

8.1 Fabrication Requirements and Acceptance Tests 8.1-1
8.1.1 Weld Procedures, Examination, and Acceptance 8.1-1
8.1.2 Structural and Pressure Tests 8.1-3
8.1.3 Leak Tests 8.1-6
8.1.4 Component Tests 8.1-7
8.1.5 Tests for Shielding Integrity 8.1-9
8.1.6 Thermal Test 8.1-12
8.1.7 Neutron Absorber Tests 8.1-15
8.1.8 Transportable Storage Canister 8.1-17

8.2 Maintenance Program 8.2-1
8.2.1 Structural and Pressure Tests of the Cask 8.2-1
8.2.2 Leak Tests 8.2-2
8.2.3 Subsystems Maintenance 8.2-3
8.2.4 Valves, Rupture Disks and Gaskets on the Containment Vessel 8.2-3
8.2.5 Shielding 8.2-3
8.2.6 Miscellaneous 8.2-4
8.2.7 Maintenance Program Schedule 8.2-4

8.3 Quick-Disconnect Valves 8.3-1

8.4 Cask Body Fabrication 8.4-1
8.4.1 General Fabrication Procedures 8.4-1
8.4.2 Description of Lead Pour Procedures 8.4-5

9.0 REFERENCES 9-1

THIS PAGE INTENTIONALLY LEFT BLANK

Port covers protect the interlid and pressure ports, which are located in the top forging and access the region between the inner and outer lids. For transport operations, solid port covers with no penetrations are installed in the interlid and pressure ports. These port covers are secured by three 3/8 - 16 UNC bolts, fabricated from SA-193, Grade B6, Type 410 stainless steel material. Each cover is sealed to the cask body by two "piston-type" (bore seal) PTFE o-rings, with a test port located between the o-rings.

Table 4.1-1 NAC-STC Containment Boundaries

Containment Condition	Content Condition	Containment Components	Allowable Test Leakage Rate/Sensitivity	Containment Boundary and Test Method	Remarks
A (Primary)	Up to 26 directly loaded intact PWR spent fuel assemblies following storage operations per 10 CFR 72	• Inner shell • Upper and lower shell rings (transition sections) • Bottom inner forging • Top forging • Inner lid • Inner lid outer metal o-ring • Inner lid interseal test port threaded plug with metal o-ring • Vent port coverplate • Vent port outer metal o-ring • Vent port interseal port threaded plug with metal o-ring • Drain port coverplate • Drain port coverplate outer metal o-ring • Drain port coverplate interseal test port plug with metal o-ring	• Allowable leakage rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium) (i.e., leaktight) • Minimum test sensitivity is $\leq 1 \times 10^{-7}$ cm^3/s (helium)	Outer o-rings of the inner lid and vent and drain port coverplates and the interseal test ports of the inner lid and vent and drain ports using evacuated envelope method (envelope provided by outer lid with test performed through the interlid port) with helium in interseal regions.	The outer o-rings are the designated boundary as access to the cask cavity to verify helium backfill conditions is not planned. Testing is performed in accordance with ANSI N14.5 requirements immediately prior to transport.

Table 4.1-1 NAC-STC Containment Boundaries (Continued)

Containment Condition	Content Condition	Containment Components	Allowable Test Leakage Rate/Sensitivity	Containment Boundary and Test Method	Remarks
B (Primary)	Up to 26 directly loaded intact PWR spent fuel assemblies for immediate transport, or canistered Yankee Class or Connecticut Yankee spent fuel assemblies, Reconfigured Fuel Assemblies, Damaged Fuel Cans or GTCC waste.	• Inner shell • Upper and lower shell rings transitional sections • Bottom inner forging • Top forging • Inner lid • Inner lid inner metal o-ring • Vent port coverplate • Vent port coverplate outer metal o-ring • Vent port coverplate interseal port plug with metal o-ring • Drain port coverplate • Drain port coverplate outer metal o-ring • Drain port coverplate interseal port plug with metal o-ring	• Allowable leakage rate is $\leq 2 \times 10^{-7}$ cm^3/s (helium) (i.e., leaktight) • Minimum test sensitivity is $\leq 1 \times 10^{-7}$ cm^3/s (helium)	• Vent port inner o-ring. • Drain port inner o-ring. • Inner lid inner o-ring. • Tests performed using the evacuated envelope method (envelope provided by the inner and outer o-rings).	Inner o-rings form the containment boundary. Testing is performed in accordance with ANSI N14.5 requirements.

Table 4.1-1 NAC-STC Containment Boundaries (Continued)

Containment Condition	Content Condition	Containment Components	Allowable Test Leakage Rate/Sensitivity	Test Location/Method	Remarks
Separate Inner Container	Up to 36 Yankee Class or up to 26 Connecticut Yankee intact or damaged (including fuel debris) spent fuel assemblies loaded in a transportable storage canister. The canister provides the separate inner container required for transport operations per 10 CFR 71.63 (b)	• Canister shell • Canister bottom • Canister shield lid • Canister vent port cover • Canister drain port cover • Canister structural lid	• Allowable leakage rate is $\leq 8 \times 10^{-8}$ cm^3/s (helium) (i.e., leaktight) • Minimum test sensitivity is $\leq 4 \times 10^{-8}$ cm^3/s (helium)	The separate inner containment provided by the canister assembly is leak tested using a helium leak detector at the shield lid to canister shell weld	This test is performed during the canister closure operations described in Section 7.6.1. Subsequently, the drain port cover is welded to the shield lid and the structural lid is welded to the canister shell, thereby providing the redundant sealing required by 10 CFR 72.236(e).

activation is calculated by light element transmutation using the in-core neutron flux spectrum produced by the SAS2H neutronics model.

The Connecticut Yankee design basis fuel source terms are presented in Table 5.2-11 and Table 5.2-12. The activated hardware source term is provided on a per unit mass basis. Source strengths are defined for five source regions: active fuel, upper end fitting, upper plenum, lower end fitting and lower plenum. The fuel assembly length, active fuel region length and fuel assembly hardware lengths are shown for the design basis fuel assemblies in Figure 5.1-5.

5.2.3.1 Connecticut Yankee Fuel Gamma Source

The design basis fuel and hardware gamma source spectra are shown in Table 5.2-11 and Table 5.2-12. The fuel gamma source contains contributions from both fission products and activation products. The spectra are presented in the standard 22 group structure used by MCBEND. The hardware gamma spectra contains contributions primarily from ^{60}Co, due to the activation of Type 304 stainless steel with either 0.5 g/kg for stainless steel clad fuel (Table 5.2-11) or 1.2 g/kg for Zircaloy clad fuel (Table 5.2-12) ^{59}Co impurity and with some minor contributions from ^{59}Ni and ^{58}Fe. The magnitude of this spectra is based on the irradiation of 1 kg of stainless steel in the in-core flux spectrum produced by the SAS2H neutronics calculation.

The activated fuel assembly hardware source strength for a given source region is determined as the product of 1) the hardware source strength per unit mass (from Table 5.2-11 and Table 5.2-12); 2) the mass of hardware present (from Table 5.2-13); 3) a mass scale factor discussed below (Table 5.2-13); and 4) a regional flux activation ratio (Table 5.2-13). The mass scale factor simply accounts for the difference in assumed cobalt concentration in the fuel cladding for stainless steel clad fuels. For stainless steel clad fuel, the SAS2H analysis is conducted based on a cobalt concentration of 0.5 g/kg. The hardware source terms in Table 5.2-11 reflect this assumed cobalt loading. However, this cobalt concentration is used only for the fuel cladding and end plugs; the remaining hardware source regions are modeled at the standard 1.2 g/kg cobalt concentration. Hence, a mass scale factor of 1.2/0.5 = 2.4 is applied to these source regions for the stainless steel clad fuels only. The Zircaloy clad fuel source terms are generated based on an assumed cobalt concentration of 1.2 g/kg for all fuel hardware, except the Zircaloy cladding material, so no adjustment is required and the mass factor for Zircaloy clad fuels is unity. The regional flux activation ratio accounts for the effects of both magnitude and spectrum variation on hardware activation. These ratios are based on empirical data (Luksic). A flux ratio of 0.2 is applied to hardware regions directly adjacent to the active core region, i.e., upper and lower

plenum. A flux ratio of 0.1 is applied to hardware regions once removed from the active core region, i.e., upper and lower end fitting region.

5.2.3.2 Connecticut Yankee Fuel Neutron Source

The neutron source results from actinide spontaneous fission and from (α,n) reactions with the oxygen in UO_2. The isotopes ^{242}Cm and ^{244}Cm characteristically produce all but a few percent of the spontaneous fission neutrons and (α,n) source in light water reactor fuel. The next largest contribution is from (α,n) reactions from ^{238}Pu. The neutron spectra from spontaneous fission is based on fission spectrum measurements of ^{235}U and ^{252}Cf. Neutron spectra from (α,n) reactions is based on Po-α-O source measurements. These spectra are included in the ORIGEN-S nuclear data libraries of the SCALE 4.3 code package. The spectra is automatically collapsed from the energy group structure of the data library into that of the MCBEND 28 group neutron cross section structure.

The effect of subcritical neutron multiplication is not directly computed in the MCBEND analysis conducted here, due to difficulties in adequately biasing the calculation. Instead, neutron source rates are scaled by a subcritical multiplication factor based on the system multiplication factor, k_{eff}:

$$\text{Scale Factor} = \frac{1}{1 - k_{eff}}$$

For the dry cask conditions of transport, the system k_{eff} is taken as 0.4, with a resulting scale factor of 1.67.

5.2.3.3 Connecticut Yankee Non-Fuel Hardware Source

Activated non-fuel hardware suitable for in situ storage in the CY–MPC includes Reactor Control Cluster Assemblies and Flow Mixer hardware. There are no source term constraints on the selection of the assembly holding these components. In the case of Flow Mixer hardware, a constraint on the permissible number and location of containing assemblies within the basket is imposed. No more than eight assemblies containing Flow Mixers can be loaded into a single

15. Drain the cask cavity by connecting an air, nitrogen or helium supply to the vent port quick-disconnect (located in the inner lid). Purge the water from the cask by pressurizing to 60 to 75 psig and hold until all water is removed (observed when no water is coming from the drain line). Turn the air, nitrogen, or helium supply off and disconnect the air, nitrogen or helium supply line from the vent port. Then, disconnect the drain line from the drain port quick-disconnect.
16. Install the drain port coverplate using new o-rings. Torque the bolts to the value indicated in Table 7-1.
17. Connect a vacuum pump to the cask cavity via the vent port quick-disconnect in the inner lid. Evacuate the cask cavity until a pressure of 3 mbar (absolute) is reached. Continue pumping for a minimum of 1 hour after reaching 3 mbar (absolute). Valve off vacuum pump from system and using a calibrated vacuum gauge (minimum gauge readability of 2.5 mbar), observe for a pressure rise. If a pressure rise (ΔP) of more than 12 mbar in ten minutes is observed, continue pumping until the pressure does not rise more than 12 mbar in ten minutes. Repeat dryness test until cavity dryness has been verified ($\Delta P < 12$ mbar in 10 minutes). Record test results in the cask loading report.
18. Without allowing air to re-enter the cask cavity, turn off and disconnect the vacuum pump. Connect a supply of helium (99.9% minimum purity) to the vent port quick-disconnect and backfill the cask cavity to 0 psig helium pressure.
19. Connect the leak detector vacuum pump to the inner lid interseal test port and evacuate the air between the metallic o-rings to 3 mbar. Hold the vacuum on the interseal region. Using the helium leak detector, verify that any detectable leak rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The sensitivity of the detector shall be $\leq 1 \times 10^{-7}$ cm^3/sec (helium).
20. Install the test port plug for the inner lid interseal test port using a new metallic o-ring and torque the plug to the value specified in Table 7-1.
21. Install the vent port coverplate using new o-rings. Torque the bolts to the value indicated in Table 7-1.
22. Connect the leak detector vacuum pump to the vent port coverplate interseal test port. Evacuate the interseal volume until a pressure of 3 mbar is reached. Using the helium leak detector, verify that any detectable leak rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The sensitivity of the detector shall be is $\leq 1 \times 10^{-7}$ cm^3/sec (helium).
23. Install the test port plug for the vent port coverplate using a new metallic o-ring and torque the plugs to the value specified in Table 7-1.
24. Repeat Steps 21 and 22 for the drain port coverplate.

25. Drain residual water from the pressure port, ensuring that the pressure port is clear to also allow water to drain from the interlid region. Install the pressure port plug and its o-ring and torque in place.
26. Install the transport pressure port cover on the pressure port. Torque the port cover bolts to the value specified in Table 7-1.
27. Perform a functional leak test on the pressure port cover by removing the o-ring test plug from the pressure port cover and, using the o-ring test fixture, pressurize the annulus between the pressure port cover o-rings to 15 psig. During a 10-minute test period, no pressure drop should be observed.
28. Install the pressure port cover interseal test port plug and o-ring and torque the plug to the value specified in Table 7-1.
29. Remove the outer lid o-ring. Clean the outer lid o-ring seating surface and groove and install a new o-ring. Install the outer lid alignment pins.
30. Attach the outer lid lifting device to the outer lid and overhead crane. Install the outer lid using the alignment pins to assist in proper seating. Remove the outer lid alignment pins. Install the outer lid bolts and torque to the value specified in Table 7-1. The bolt torquing sequence is shown on the outer lid.
31. Attach a supply of air or helium to the interlid port quick-disconnect. Backfill the interlid volume to 15 psig air or helium and hold for 10 minutes. No loss of pressure is permitted. Disconnect air or helium supply.
32. Install the interlid port cover using new metallic o-rings. Torque the interlid port cover bolts to the value specified in Table 7-1.
33. Remove the o-ring test plug from the interlid port cover and, using the o-ring test fixture, pressurize the o-ring annulus to 15 psig with air or helium. Isolate the annulus and hold for 10 minutes. No loss of pressure is permitted.
34. Remove the air or helium supply and vent the annulus pressure. Replace the o-ring on the interlid port cover test plug, install the test plug and torque it to the value specified in Table 7-1.
35. Perform final external decontamination and perform survey to verify acceptable level of removable contamination to ensure compliance with 49 CFR 173.443. Perform final radiation survey. Record the survey results in the cask loading report.
36. Perform final visual inspection to verify assembly of the NAC-STC in accordance with the Certificate of Compliance. Verify that the loading procedure and checklist are appropriately completed and signed off.

7.1.3.2 Loading Canistered Fuel or GTCC Waste

Canistered fuel or canistered GTCC waste is loaded into the NAC-STC using a transfer cask. This procedure assumes that the canister has been previously loaded, drained, vacuum dried, backfilled with helium and welded closed. The canister may have been retrieved from dry storage, or it may have been loaded and sealed immediately prior to loading in the NAC-STC. This procedure assumes the sealed canister conforms to the design basis of the NAC-STC and that the canister is already in the transfer cask. The NAC-STC is assumed to be positioned in the area designated for dry canister loading, the inner and outer lids are removed, that the correct bottom spacer is installed in the cask cavity, that the adapter ring and transfer adapter plate have been installed (refer to Section 7.1.2.2) and that the transfer cask door locking pins are removed.

1. Attach the transfer cask yoke to the cask handling crane hook.
2. Engage the transfer cask yoke to the trunnion of the transfer cask.
3. Raise the transfer cask over the NAC-STC cask and lower it until it rests on the transfer cask adapter plate. Remove and store the transfer cask lifting yoke.
4. Attach the hydraulic system to the transfer cask doors.
5. Attach the two (2) canister 3-legged lifting sling sets to the hoist rings in the canister lid. Attach the opposite end of the slings to the crane hook.
6. Raise the canister just enough to take the canister weight off of the transfer cask bottom doors.
7. Open the transfer cask shield doors.
8. Lower the canister into the NAC-STC cask. Exercise caution to avoid contact with the interior cavity wall.
9. Disconnect and remove the canister lifting sling.
10. Close the transfer cask bottom doors and install the door locking pins.
11. Retrieve the transfer cask lifting yoke and engage the transfer cask trunnions. Lift the transfer cask from the adapter plate. Store the transfer cask and transfer cask lifting yoke in the designated locations.
12. Install the NAC-MPC canister top spacer (Yankee-MPC canister only).
13. Retrieve the adapter plate lifting sling and attach it to the adapter plate.
14. Remove the four (4) bolts attaching the adapter plate to the NAC-STC. Remove the adapter plate and store it in the designated location. Remove the adapter ring and bolts. Install the inner lid alignment pins.

15. Remove the inner lid o-rings and clean inner lid o-ring groove surfaces. Replace the metallic o-rings on the inner lid, carefully inspecting the new o-rings for damage prior to installation. Secure the o-rings in the groove using the o-ring clips and screws.
16. Attach the inner lid lifting slings to an auxiliary crane hook, lift the inner lid and place it on the cask using the inner lid alignment pins to assist in proper lid seating and orientation. Visually verify proper lid position.
17. Disconnect the lid lifting device from the crane hook and remove it from the inner lid.
18. Install at least 10 inner lid bolts equally spaced on the bolt circle to hand tight. Remove the inner lid alignment pins.
19. Install the remaining inner lid bolts and torque all of the bolts to the torque value specified in Table 7-1. The bolt torquing sequence is shown on the inner lid.
20. Install the drain port coverplate using new metallic o-rings. Torque the bolts to the value specified in Table 7-1.
21. Connect the vacuum pump to the cask vent port and evacuate the cask cavity to a stable vacuum pressure of 3 mbar (approximately 3 mm of Hg). Without allowing air to re-enter the cask, backfill the cavity with helium (99.9% minimum purity) to 0 psig. Disconnect the helium supply.
22. Remove the metallic o-rings in the vent port coverplate and clean and inspect the o-ring groove. Install new metallic o-rings in the vent port coverplate and install the coverplate. Torque the coverplate bolts to the value specified in Table 7-1.
23. Connect the leak detector vacuum pump to the inner lid interseal test port and evacuate the air between the metallic o-rings until a pressure of 3 mbar is reached. Hold the vacuum on the interseal region. Using the helium leak detector, verify that any detectable leak rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The sensitivity of the detector shall be $\leq 1 \times 10^{-7}$ cm^3/sec (helium).
24. Install the test port plug for the inner lid interseal test port using a new metallic o-ring and torque the plug to the value specified in Table 7-1.
25. Connect the leak detector vacuum pump to the vent port coverplate interseal test port. Evacuate the interseal volume until a pressure of 3 mbar is reached. Using the helium leak detector, verify that any detectable leak rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The sensitivity of the detector shall be $\leq 1 \times 10^{-7}$ cm^3/sec (helium).
26. Install the test port plug for the vent port coverplate using a new metallic o-ring and torque the plug to the value specified in Table 7-1.
27. Repeat Steps 25 and 26 for the drain port coverplate test port.

28. Remove the outer lid metallic o-ring. Clean the outer lid o-ring seating surface and groove. Install a new outer lid o-ring. Install the outer lid alignment pins.
29. Attach the outer lid lifting device to the outer lid and overhead crane. Install the outer lid using the alignment pins to assist in proper seating. Remove the outer lid alignment pins. Install the outer lid bolts and torque to the value specified in Table 7-1. The bolt torquing sequence is shown on the outer lid.
30. Attach a supply of air or helium to the interlid port quick-disconnect. Backfill the interlid volume to 15 psig air or helium and hold for 10 minutes. No loss of pressure is permitted. Disconnect air or helium supply.
31. Install the transport interlid port cover in the interlid port using new o-rings. Torque the interlid port cover bolts to the value specified in Table 7-1.
32. Remove the o-ring test plug from the interlid port cover and, using the o-ring test fixture, pressurize the o-ring annulus to 15 psig with air or helium. Isolate the annulus and hold for 10 minutes. No loss of pressure drop is permitted.
33. Vent the annulus pressure, remove the air or helium supply, replace the o-ring on the interlid port cover test plug and install the test plug. Torque the plug to the value specified in Table 7-1.
34. Perform final external decontamination and perform survey to verify acceptable level of removable contamination to ensure compliance with 49 CFR 173.443. Perform final radiation survey. Record the survey results in the cask loading report.
35. Perform final visual inspection to verify assembly of the NAC-STC in accordance with the Certificate of Compliance. Verify that the loading procedure and checklist are appropriately completed and signed off.

THIS PAGE INTENTIONALLY LEFT BLANK

7.3 Outline of Procedures for Unloading the Cask

This section presents the procedures to be followed for unloading the cask following transport of directly loaded fuel, canistered fuel or canistered GTCC waste.

7.3.1 Receiving Inspection

1. Perform radiation and removable contamination surveys in accordance with 10 CFR 20.1906, 49 CFR 173.441 and 173.443 requirements.
2. Remove the personnel barrier/enclosure and complete radiation and removable contamination surveys at the cask surfaces.
3. Visually inspect the NAC-STC while secured to the transport vehicle in the horizontal orientation for any signs of damage. Record any damage in the cask unloading report.
4. Secure the transport vehicle. Attach slings to the top impact limiter lifting points, remove impact limiter lock wires, jam nuts, attachment nuts and retaining rods, and remove the impact limiter. Store the impact limiter upright. Repeat the operation to remove the bottom impact limiter. Complete radiation and removable contamination surveys for exposed cask surfaces.
5. Release the tiedown assembly from the front support by removing the front tiedown bolts and lock washers.
6. Attach a sling to the tiedown assembly lifting eyes and remove the tiedown assembly from the transport vehicle.
7. Attach the cask lifting yoke to a crane hook with the appropriate load rating. Engage the two yoke arms with the lifting trunnions at the top end of the cask. Rotate/lift the cask to the vertical orientation and raise the cask off of the pillow blocks attached to the rear support structure of the transport vehicle. Place the cask in the vertical orientation in a decontamination area or other location identified by the user.
8. Wash any road dust and dirt off of the cask and decontaminate cask exterior, as required by contamination survey results.

7.3.2 Preparation of the NAC-STC Cask for Unloading

The NAC-STC may contain fuel directly loaded into a basket within the cask, or a sealed transportable storage canister containing fuel or GTCC waste. Unloading of fuel from the directly loaded cask basket typically takes place under water in the spent fuel pool cask

loading area. This procedure assumes that the cask is vertical in the reactor cask decontamination area, and that access is available to the top end of the NAC-STC. Canister unloading would be performed dry using a transfer cask. Canister unloading would take place in the reactor cask receiving area, or other location identified by the user. This procedure also assumes that the cask is vertical in the work area and that access to the top of the cask is available.

7.3.2.1 Preparation for Unloading the NAC-STC Cask (Directly Loaded Fuel Configuration)

1. Verify that excessive pressure does not exist in the interlid region by removing the interlid port cover and attaching a pressure test fixture to the interlid port quick-disconnect that will allow the monitoring of the cask interlid region for any pressure buildup that may have occurred during transport. If a positive pressure exists, connect a vent/drain line to the interlid quick-disconnect and vent the pressure to the off-gas system.
2. Remove the outer lid bolts and install the outer lid alignment pins and outer lid lifting eye bolts.
3. Attach the outer lid lifting device to the outer lid lifting eye bolts and the overhead crane. Remove the outer lid and place it aside in a temporary storage area. Protect the o-ring and the o-ring groove of the lid from damage.
4. Remove the port coverplates from the drain and vent ports in the inner lid with caution. Attach a pressure test fixture to the vent port that will allow the monitoring of the cask cavity for any pressure buildup that may have occurred during transport. If a positive pressure exists, vent the pressure to the off-gas system.
5. Connect a demineralized water supply line to the drain port quick-disconnect and a drain line to the vent port quick-disconnect. Route the drain line to a radioactive waste treatment system or the spent fuel pool.
6. To facilitate cooldown and to minimize thermal effects to the cask and its contents, slowly (8 gpm for 10 minutes, followed by up to 20 gpm for remainder) fill the cask cavity with clean demineralized water (cavity is full when water flows out of the vent port drain line). Circulate water through the cask until the water leaving the vent port drain line is within 50°F of the average spent fuel pool water temperature.
7. Disconnect the fill line from the drain port quick-disconnect in the inner lid (Note: Leave a short drain line attached to the vent port quick-disconnect for continuous venting).

Table of Contents

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM 8-1

8.1 Fabrication Requirements and Acceptance Tests 8.1-1
8.1.1 Weld Procedures, Examination, and Acceptance 8.1-1
8.1.2 Structural and Pressure Tests 8.1-3
8.1.3 Leak Tests 8.1-6
8.1.4 Component Tests 8.1-7
8.1.5 Tests for Shielding Integrity 8.1-9
8.1.6 Thermal Test 8.1-12
8.1.7 Neutron Absorber Tests 8.1-15
8.1.8 Transportable Storage Canister 8.1-17

8.2 Maintenance Program 8.2-1
8.2.1 Structural and Pressure Tests of the Cask 8.2-1
8.2.2 Leak Tests 8.2-2
8.2.3 Subsystems Maintenance 8.2-3
8.2.4 Valves, Rupture Disks and Gaskets on the Containment Vessel 8.2-3
8.2.5 Shielding 8.2-3
8.2.6 Miscellaneous 8.2-4
8.2.7 Maintenance Program Schedule 8.2-4

8.3 Quick-Disconnect Valves 8.3-1

8.4 Cask Body Fabrication 8.4-1
8.4.1 General Fabrication Procedures 8.4-1
8.4.2 Description of Lead Pour Procedures 8.4-5

List of Figures

Figure 8.4-1 Arrangement of Lead Pour Equipment..... 8.4-9

List of Tables

Table 8.2-1 Maintenance Program Schedule..... 8.2-5

the requirements of ASME Code, Section III, Division I, Subsection NB, Article NB-4450. The repaired weld area shall be retested and reinspected in accordance with the above test requirements and acceptance standards.

The final fabrication verification leak testing of the NAC-STC containment boundary closures consists of a series of leak tests of the closure metallic o-rings using (minimum 99.9 percent pure) helium as a tracer gas and a helium Leak Detection system to demonstrate a leak rate $\leq 2 \times 10^{-7}$ cm^3/sec (helium) with a minimum sensitivity of 1×10^{-7} cm^3/sec (helium). Since both the inner and outer o-rings of the inner lid and vent and drain port coverplates, and the interseal test ports could be part of the containment boundary depending on the transport configuration, the test regimen shall demonstrate that these components meet the leaktight requirement as defined by ANSI N14.5-1997. All of the leak tests shall be performed in accordance with the requirements of ANSI N14.5-1997, using approved procedures.

The detailed procedures for the NAC-STC cask leak testing are presented in Sections 7.1.3, 7.2 and 7.4.

No indicated leak within the range of the sensitivity of the test is permitted and shall be cause for rejection of the item being tested. Seal replacement or other corrective actions will be taken to correct the leak. The item shall then be retested and inspected in accordance with the above test requirements and acceptance standards.

8.1.4 Component Tests

Tests performed on individual components are designed to ensure that the component meets the design requirements for correct and proper operation of the cask system.

Acceptance criteria are established based on the functions and design requirements of the component being tested.

8.1.4.1 Valves

There are no valves that are part of the NAC-STC containment boundary for transport. Quick-disconnects are installed in the vent, drain and interseal test port openings in the inner lid to

provide access to the cavity, and in the interlid port to provide access to the interlid region. These quick-disconnects serve as valves when the mating parts are connected, and are used to connect ancillary equipment to the cask cavity for filling, draining, drying, backfilling, gas sampling, and leak testing operations. Upon removal of the external fitting, the valve in the quick-disconnect closes automatically. The design and selection of the quick-disconnects is based on similar equipment and procedures used with other NRC-approved storage and transport casks. For transport, the quick-disconnects are sealed inside the transport containment boundary using a bolted coverplate fitted with two metallic o-ring seals. These seals are leak tested before each use.

There are no rupture disks on the NAC-STC.

Two self-actuating pressure relief valves are installed on the external shell of the neutron shield to provide for venting of vapor from the shielding material during transport thermal accident conditions. These valves have stainless steel bodies and an operating pressure range of zero to 200 psig with an adjustable cracking pressure within this range. The cracking pressure is set at 10 psig. These relief valves do not provide a safety function, but have been designed to minimize recovery efforts in the unlikely event of a neutron shield overpressure condition.

8.1.4.2 Gaskets

The outer lid, inner lid, drain port coverplate, vent port coverplate, interlid port cover, pressure port cover, and interseal test plug gaskets are o-rings. The outer metallic o-ring of the inner lid, the outer metallic o-rings on the vent and drain port coverplates, and the interseal test plug metallic o-rings for the inner lid, the vent port coverplate and the drain port coverplate, are the gaskets that are part of the primary containment boundary. The inner metallic o-rings of the inner lid, vent port coverplate and drain port coverplate, the metallic o-ring of the outer lid, and the PTFE o-rings of the interlid and pressure port covers provide a secondary closure to the cask contents. For transport without interim storage, the containment boundary is formed by the inner o-rings of the inner lid and vent and drain port coverplates. A second boundary is formed by the o-rings of the outer lid and interseal and pressure port covers.

The o-ring replacement schedule depends upon the o-ring material. The metallic o-ring(s) of any component shall be replaced prior to reinstallation of the component. The PTFE o-rings of the interlid and pressure ports will be visually inspected prior to each use, and replaced if necessary. The PTFE o-rings shall be replaced at least once every two years during cask transport

8.1.7 Neutron Absorber Tests

Neutron absorber material (commercially available as BORAL®), in the form of sheets consisting of boron-carbide evenly dispersed within a matrix of aluminum and clad with aluminum, is used in the NAC-MPC transportable storage canister fuel baskets. BORAL® is manufactured by AAR Advanced Structures (AAR) of Livonia, Michigan, under a Quality Assurance/Quality Control program in conformance with the requirements of 10 CFR 50, Appendix B. The computer-aided manufacturing process consists of several steps - the first being the mixing of the aluminum and boron-carbide powders that form the core of the finished material, with the amount of each powder a function of the desired ^{10}B areal density. The methods used to control the weight and blend the powders are patented and proprietary processes of AAR.

After manufacturing, test samples from each batch of BORAL® neutron absorber (poison) sheets shall be tested using wet chemistry or neutron absorption techniques to verify the presence, proper distribution, and minimum weight percent of ^{10}B. The tests shall be performed in accordance with approved written procedures.

8.1.7.1 Neutron Absorber Material Sampling Plan

The neutron absorber sampling plan is selected to demonstrate a 95/95 (95% probability and 95% confidence level) statistical confidence level in the neutron absorber sheet material compliance with the specification. In addition to the specified sampling plan, each sheet of material is visually and dimensionally inspected using at least 6 measurements (along the edges near each corner and the longitudinal centerline) on each sheet. No rejected neutron absorber sheet is used. The sampling plan is supported by written and approved procedures.

The sampling plan requires that a coupon sample be taken from each sheet of the first set of 100 sheets of absorber material. Thereafter, coupon samples are taken from 20 randomly selected sheets from each set of 100 sheets. This 1 in 5 sampling plan continues until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder, aluminum powder, or aluminum extrusion), or a process change, at which time the sampling process is reinitiated as previously described. The sheet samples are indelibly marked and recorded for identification. This identification is used to document neutron absorber test results, which become part of the quality record documentation package.

8.1.7.2 Wet Chemistry Test Performance

An approved facility with chemical analysis capability shall be selected to perform the wet chemistry tests. The tests will ensure the presence of boron and enable the calculation of the ^{10}B areal density.

The most common method of verifying the acceptability of neutron absorber material is the wet chemistry method—a chemical analysis where the aluminum is separated from a sample with known thickness and volume. The remaining boron-carbide material is weighed and the areal density of ^{10}B is computed. A statistical conclusion about the BORAL® sheet from which the sample was taken and that batch of BORAL® sheets may then be drawn based on the test results and the established manufacturing processes previously noted.

8.1.7.3 Neutron Absorption Test Performance

An approved facility with a neutron source and neutron detection capability shall be selected to perform the described tests, if the neutron absorption test method is used. The tests will assure that the neutron absorption capacity of the material tested is equal to, or higher than, the given reference value and will verify the uniformity of boron distribution. The principle of measurement of neutron absorption is that the presence of boron results in a reduction of neutron flux between the thermalized neutron source and the neutron detector—depending on the material thickness and boron content.

Typical test equipment will consist of thermal neutron source equipment, a neutron detector and a counting instrument. The test equipment is calibrated using BORAL standards, whose ^{10}B content has been checked and verified by an independent method such as chemical analysis. The highest permissible counting rate is determined from the neutron counting rates of the reference sheet(s), which should be ground to the minimum allowable plate thickness. This calibration process shall be repeated daily (every 24 hours) while tests are being performed.

8.1.7.4 Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the minimum ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube drawings. The neutron absorption test shall be considered acceptable if the neutron count determined for each test

specimen is less than or equal to the highest permissible neutron count rate determined from the BORAL® standard, which is based on the ^{10}B areal density specified on the fuel tube drawings. Any specimen not meeting the acceptance criteria for either test method shall be rejected and all of the sheets from that batch shall be similarly rejected.

8.1.8 Transportable Storage Canister

The transportable storage canister is constructed of Type 304L stainless steel and is fabricated in two sections. Each section has a seam weld, and the sections are joined by a circumferential weld. In joining the two sections, the seam welds shall not be aligned within 45° circumferentially. The welded cylinder is closed at the bottom by a circular plate welded to the shell wall. Two field-installed circular plates, welded to the canister shell wall following fuel loading close the top of the cylinder.

The transportable storage canister is a welded closed component. The canister serves as a secondary containment boundary for intact spent fuel and as the "separate inner container" required by 10 CFR 71.63(b) for failed fuel for transport. With its double lid configuration the canister provides the redundant sealing required by 10 CFR 72.236(e) and serves as the confinement boundary component of the NAC-MPC System during storage of spent fuel in the vertical concrete cask.

The finished surfaces of all canister welds are visually examined in accordance with ASME Code Section V, Article 9, to verify that the components are assembled in accordance with the License Drawings (Section 1.3.2) and that the components are free of nicks, gouges, and other damage. The acceptance criteria for the visually examined welds is in accordance with ASME Code Section VIII, Division 1, UW-35 and UW-36.

The seam and girth welds in the transportable storage canister shell are full-penetration welds that are radiographic (RT) examined in accordance with ASME Code Section V, Article 2. The acceptance criteria for the RT-examined welds is that specified in ASME Code Section III, Subsection NB, Article NB-5320. The canister shell to bottom plate weld is a full-penetration double-bevel weld with an inside fillet weld that is ultrasonic examined in accordance with ASME Code Section V, Article 5, with acceptance criteria as specified in ASME Code Section

III, Subsection NB, Article NB-5330. The final surfaces of the seam and girth welds in the canister and the canister shell to bottom plate weld are also liquid penetrant examined in accordance with ASME Code Section V, Article 6, with the acceptance criteria being that specified in ASME Code Section III, Subsection NB, Article NB-5350.

Field installed partial-penetration groove welds attach the shield (inner) lid to the canister shell and the vent port and the drain port coverplates to the shield lid, after the canister is loaded. The structural lid is attached to the canister shell by a partial penetration weld. The root and final surfaces of the shield lid weld are liquid penetrant examined in accordance with the ASME Code Section V, Article 6. Acceptance criteria are as specified in ASME Code Section III, Division 1, Subsection NB, Article NB-5330. The vent port and the drain port coverplate to shield lid welds are liquid penetrant examined, i.e., root and final surfaces, in accordance with ASME Code Section V, Article 6. Acceptance criteria is specified in ASME Code Section III, Division 1, Subsection NB, Article NB-5350. The structural lid weld is either ultrasonic (UT) examined in accordance with the ASME Code, Section V, Article 5 with the final weld surface liquid penetrant examined in accordance with ASME Code, Section V, Article 6, or progressively liquid penetrant examined in accordance with the ASME Code, Section V, Article 6. Acceptance criteria is specified in ASME Code Section III, Division 1, Subsection NB, Article NB-5330 (ultrasonic) and Article NB-5350 (liquid penetrant). Following completion of the shield lid to canister shell weld and the drain port coverplate to shield lid welds, the canister is leak tested in accordance with ASME Code Section V, Article 10, Appendix IV, using a leak rate test sensitivity of 1×10^{-7} cm^3/sec (helium).

The fabricator of the transportable storage canister will establish a written weld inspection plan in accordance with an approved quality assurance program. The weld inspection plan will include visual, liquid penetrant, ultrasonic, and radiographic examination. In addition, the weld inspection plan will identify the welds to be examined, the sequence of the examinations, the type of examination method to be used, and the criteria for acceptance of the weld in accordance with the applicable sections of the ASME Code.