FuelSolutions™ W74 Canister Transportation Safety Analysis Report

Revision 5
August 2003

Document No. WSNF-123
Docket No. 71-9276

Prepared by:

BNFL Fuel Solutions Corporation
Campbell, California

©2003 BNFL Fuel Solutions Corporation
All Rights Reserved

Approved for Release:

Revision: 5

Date: 08-07-03

LIST OF EFFECTIVE PAGES

Page	Active Revision	Page	Active Revision	Page	Active Revision	Page	Active Revision
i	5	1.1-1	1	1.3-3	0	2.4-3	0
ii	5	1.1-2	0	1.3-4	0	2.4-4	0
iii	5	1.1-3	1	1.3-5	0	2.5-1	0
iv	5	1.1-4	1	1.3-6	0	2.5-2	0
v	5	1.2-1	0	1.3-7	0	2.6-1	0
vi	5	1.2-2	0	1.3-8	0	2.6-2	0
vii	5	1.2-3	0	1.3-9	0	2.6-3	0
viii	5	1.2-4	3	1.3-10	0	2.6-4	0
ix	5	1.2-5	3	2-1	1	2.6-5	0
x	5	1.2-6	5	2-2	1	2.6-6	0
xi	5	1.2-7	0	2.1-1	0	2.6-7	0
xii	5	1.2-8	5	2.1-2	1	2.6-8	0
xiii	5	1.2-9	1	2.1-3	1	2.6-9	0
xiv	5	1.2-10	1	2.1-4	1	2.6-10	0
xv	5	1.2-11	1	2.1-5	1	2.6-11	0
xvi	5	1.2-12	1	2.1-6	1	2.6-12	0
xvii	5	1.2-13	1	2.1-7	1	2.6-13	0
xviii	5	1.2-14	0	2.1-8	1	2.6-14	0
xix	5	1.2-15	0	2.1-9	1	2.6-15	0
xx	5	1.2-16	0	2.1-10	1	2.6-16	0
xxi	5	1.2-17	0	2.1-11	0	2.6-17	0
xxii	5	1.2-18	0	2.1-12	0	2.6-18	0
xxiii	5	1.2-19	5	2.1-13	0	2.6-19	0
xxiv	5	1.2-20	5	2.1-14	0	2.6-20	0
1-1	0	1.2-21	5	2.1-15	0	2.6-21	0
1-2	0	1.2-22	5	2.1-16	0	2.6-22	0
1-3	0	1.2-23	5	2.2-1	1	2.6-23	0
1-4	0	1.2-24	5	2.2-2	0	2.6-24	0
1-5	0	1.2-25	0	2.2-3	0	2.6-25	0
1-6	0	1.2-26	3	2.2-4	0	2.6-26	0
1-7	0	1.2-27	3	2.3-1	0	2.6-27	0
1-8	0	1.2-28	0	2.3-2	1	2.6-28	0
1-9	0	1.2-29	0	2.3-3	0	2.6-29	0
1-10	0	1.2-30	0	2.3-4	1	2.6-30	0
1-11	0	1.3-1	0	2.3-5	1	2.6-31	0
1-12	0	1.3-2	0	2.3-6	1	2.6-32	1
1-13	0	W74-110	5	2.3-7	1	2.6-33	0
1-14	0	W74-120	5	2.3-8	1	2.6-34	0
1-15	0	W74-121	6	2.3-9	1	2.6-35	0
1-16	0	W74-122	5	2.3-10	1	2.6-36	0
1-17	0	W74-130	5	2.3-11	1	2.6-37	0
1-18	0	W74-140	5	2.3-12	1	2.6-38	0
1-19	0	W74-150	5	2.4-1	0	2.6-39	0
1-20	0	3319	6	2.4-2	0	2.6-40	0

LIST OF EFFECTIVE PAGES

Page	Active Revision	Page	Active Revision	Page	Active Revision	Page	Active Revision
2.6-41	0	2.7-13	0	2.7-57	0	2.10-1	0
2.6-42	0	2.7-14	0	2.7-58	0	2.10-2	0
2.6-43	0	2.7-15	1	2.7-59	0	2.11-1	0
2.6-44	0	2.7-16	1	2.7-60	0	2.11-2	0
2.6-45	0	2.7-17	1	2.7-61	0	2.12-1	0
2.6-46	0	2.7-18	1	2.7-62	0	2.12-2	0
2.6-47	1	2.7-19	0	2.7-63	0	2.12-3	0
2.6-48	1	2.7-20	1	2.7-64	0	2.12-4	0
2.6-49	1	2.7-21	1	2.7-65	0	2.12-5	0
2.6-50	1	2.7-22	0	2.7-66	0	2.12-6	0
2.6-51	1	2.7-23	0	2.7-67	0	2.12-7	0
2.6-52	1	2.7-24	0	2.7-68	0	2.12-8	0
2.6-53	1	2.7-25	0	2.7-69	0	2.12-9	0
2.6-54	1	2.7-26	0	2.7-70	4	2.12-10	1
2.6-55	1	2.7-27	1	2.7-71	1	2.12-11	0
2.6-56	1	2.7-28	1	2.7-72	1	2.12-12	0
2.6-57	1	2.7-29	0	2.7-73	1	2.12-13	0
2.6-58	1	2.7-30	0	2.7-74	1	2.12-14	0
2.6-59	1	2.7-31	1	2.7-75	1	2.12-15	0
2.6-60	1	2.7-32	0	2.7-76	1	2.12-16	0
2.6-61	1	2.7-33	0	2.7-77	1	2.12-17	0
2.6-62	1	2.7-34	0	2.7-78	1	2.12-18	0
2.6-63	0	2.7-35	0	2.7-79	1	2.12-19	0
2.6-64	0	2.7-36	0	2.7-80	1	2.12-20	0
2.6-65	0	2.7-37	0	2.7-81	1	2.12-21	0
2.6-66	0	2.7-38	0	2.7-82	1	2.12-22	0
2.6-67	0	2.7-39	0	2.7-83	1	2.12-23	0
2.6-68	0	2.7-40	0	2.7-84	1	2.12-24	0
2.6-69	0	2.7-41	0	2.7-85	1	2.12-25	0
2.6-70	0	2.7-42	0	2.7-86	1	2.12-26	0
2.6-71	0	2.7-43	0	2.7-87	1	2.12-27	0
2.6-72	0	2.7-44	0	2.7-88	1	2.12-28	0
2.7-1	0	2.7-45	0	2.7-89	1	2.12-29	1
2.7-2	0	2.7-46	0	2.7-90	1	2.12-30	0
2.7-3	0	2.7-47	0	2.7-91	1	2.12-31	1
2.7-4	1	2.7-48	0	2.7-92	1	2.12-32	1
2.7-5	0	2.7-49	0	2.7-93	1	2.12-33	1
2.7-6	0	2.7-50	0	2.7-94	1	2.12-34	1
2.7-7	0	2.7-51	0	2.7-95	1	2.12-35	0
2.7-8	0	2.7-52	0	2.7-96	1	2.12-36	0
2.7-9	0	2.7-53	0	2.8-1	0	2.12-37	0
2.7-10	0	2.7-54	0	2.8-2	0	2.12-38	0
2.7-11	0	2.7-55	0	2.9-1	0	2.12-39	0
2.7-12	0	2.7-56	0	2.9-2	0	2.12-40	0

LIST OF EFFECTIVE PAGES

Page	Active Revision	Page	Active Revision	Page	Active Revision	Page	Active Revision
2.12-41	0	3.3-3	0	3.5-3	1	4.3-1	0
2.12-42	0	3.3-4	0	3.5-4	1	4.3-2	0
2.12-43	0	3.3-5	0	3.5-5	1	5-1	0
2.12-44	0	3.3-6	0	3.5-6	4	5-2	0
2.12-45	0	3.4-1	4	3.5-7	1	5.1-1	0
2.12-46	0	3.4-2	1	3.5-8	1	5.1-2	0
2.12-47	0	3.4-3	1	3.5-9	1	5.1-3	1
2.12-48	0	3.4-4	1	3.5-10	1	5.1-4	0
2.12-49	0	3.4-5	1	3.6-1	0	5.2-1	1
2.12-50	0	3.4-6	1	3.6-2	0	5.2-2	1
2.12-51	0	3.4-7	5	3.6-3	0	5.2-3	1
2.12-52	0	3.4-8	4	3.6-4	0	5.2-4	1
2.12-53	1	3.4-9	4	3.6-5	0	5.2-5	1
2.12-54	1	3.4-10	4	3.6-6	1	5.2-6	1
2.12-55	1	3.4-11	4	3.6-7	1	5.2-7	1
2.12-56	1	3.4-12	4	3.6-8	1	5.2-8	1
3-1	4	3.4-13	5	3.6-9	5	5.2-9	1
3-2	1	3.4-14	4	3.6-10	4	5.2-10	1
3.1-1	4	3.4-15	0	3.6-11	1	5.2-11	1
3.1-2	0	3.4-16	0	3.6-12	5	5.2-12	1
3.1-3	0	3.4-17	0	3.6-13	4	5.2-13	1
3.1-4	1	3.4-18	0	3.6-14	4	5.2-14	1
3.1-5	5	3.4-19	0	3.6-15	4	5.3-1	1
3.1-6	5	3.4-20	0	3.6-16	4	5.3-2	1
3.1-7	5	3.4-21	0	3.6-17	1	5.3-3	1
3.1-8	5	3.4-22	0	3.6-18	1	5.3-4	1
3.1-9	5	3.4-23	0	3.6-19	1	5.3-5	1
3.1-10	5	3.4-24	0	3.6-20	1	5.3-6	1
3.1-11	0	3.4-25	0	3.6-21	4	5.3-7	1
3.1-12	5	3.4-26	0	3.6-22	0	5.3-8	1
3.1-13	5	3.4-27	0	3.6-23	0	5.3-9	1
3.1-14	4	3.4-28	1	3.6-24	0	5.3-10	1
3.1-15	5	3.4-29	1	3.6-25	0	5.3-11	1
3.1-16	4	3.4-30	1	3.6-26	0	5.3-12	1
3.2-1	1	3.4-31	1	3.6-27	0	5.3-13	1
3.2-2	1	3.4-32	1	3.6-28	0	5.3-14	1
3.2-3	0	3.4-33	0	4-1	0	5.3-15	1
3.2-4	0	3.4-34	0	4-2	0	5.3-16	1
3.2-5	0	3.4-35	0	4.1-1	1	5.3-17	1
3.2-6	1	3.4-36	0	4.1-2	1	5.3-18	1
3.2-7	0	3.4-37	0	4.1-3	0	5.3-19	1
3.2-8	0	3.4-38	0	4.1-4	0	5.3-20	1
3.3-1	0	3.5-1	0	4.2-1	0	5.3-21	1
3.3-2	0	3.5-2	1	4.2-2	0	5.3-22	1

LIST OF EFFECTIVE PAGES

Page	Active Revision	Page	Active Revision	Page	Active Revision	Page	Active Revision
5.4-1	1	6.3-15	1	6.4-19	1	6.6-33	1
5.4-2	1	6.3-16	1	6.4-20	1	6.6-34	1
5.4-3	1	6.3-17	1	6.4-21	1	6.6-35	1
5.4-4	1	6.3-18	1	6.4-22	1	6.6-36	1
5.4-5	1	6.3-19	1	6.4-23	1	6.6-37	1
5.4-6	1	6.3-20	1	6.4-24	1	6.6-38	1
5.4-7	1	6.3-21	1	6.4-25	1	6.6-39	1
5.4-8	0	6.3-22	1	6.4-26	1	6.6-40	1
5.5-1	1	6.3-23	1	6.5-1	0	6.6-41	1
5.5-2	1	6.3-24	1	6.5-2	0	6.6-42	1
5.5-3	1	6.3-25	1	6.5-3	0	6.6-43	1
5.5-4	1	6.3-26	1	6.5-4	0	6.6-44	1
5.5-5	0	6.3-27	1	6.6-1	1	6.6-45	1
5.5-6	0	6.3-28	1	6.6-2	1	6.6-46	1
5.5-7	1	6.3-29	1	6.6-3	1	6.6-47	1
5.5-8	0	6.3-30	1	6.6-4	1	6.6-48	1
5.5-9	1	6.3-31	1	6.6-5	1	6.6-49	1
5.5-10	1	6.3-32	1	6.6-6	1	6.6-50	3 (4/30/02)
5.5-11	1	6.3-33	1	6.6-7	1	6.6-51	3 (4/30/02)
5.5-12	1	6.3-34	1	6.6-8	1	6.6-52	3 (4/30/02)
6-1	0	6.3-35	1	6.6-9	1	6.6-53	3 (4/30/02)
6-2	0	6.3-36	1	6.6-10	1	6.6-54	1
6.1-1	0	6.3-37	1	6.6-11	1	6.6-55	3 (4/30/02)
6.1-2	1	6.3-38	1	6.6-12	1	6.6-56	3 (4/30/02)
6.1-3	1	6.3-39	1	6.6-13	1	6.6-57	1
6.1-4	0	6.3-40	1	6.6-14	1	6.6-58	1
6.2-1	0	6.4-1	0	6.6-15	1	6.6-59	1
6.2-2	0	6.4-2	0	6.6-16	1	6.6-60	1
6.2-3	0	6.4-3	0	6.6-17	1	6.6-61	1
6.2-4	0	6.4-4	1	6.6-18	1	6.6-62	1
6.3-1	1	6.4-5	1	6.6-19	1	6.6-63	1
6.3-2	1	6.4-6	1	6.6-20	1	6.6-64	1
6.3-3	1	6.4-7	1	6.6-21	1	7-1	1
6.3-4	1	6.4-8	1	6.6-22	1	7-2	0
6.3-5	1	6.4-9	1	6.6-23	1	7.1-1	1
6.3-6	1	6.4-10	1	6.6-24	1	7.1-2	1
6.3-7	1	6.4-11	1	6.6-25	1	7.1-3	1
6.3-8	1	6.4-12	1	6.6-26	1	7.1-4	1
6.3-9	1	6.4-13	1	6.6-27	1	7.2-1	1
6.3-10	1	6.4-14	1	6.6-28	1	7.2-2	0
6.3-11	1	6.4-15	1	6.6-29	1	7.3-1	0
6.3-12	1	6.4-16	1	6.6-30	1	7.3-2	0
6.3-13	1	6.4-17	1	6.6-31	1	7.4-1	0
6.3-14	1	6.4-18	1	6.6-32	1	7.4-2	0

LIST OF EFFECTIVE PAGES

Page	Active Revision
8-1	4
8-2	0

This page intentionally left blank.

TABLE OF CONTENTS

Section	Title	Page
1.	**GENERAL INFORMATION**	**1-1**
1.1	Introduction	1.1-1
1.2	Package Description	1.2-1
1.2.1	Packaging	1.2-1
1.2.1.1	FuelSolutions™ W74 Canister	1.2-2
1.2.1.2	Other FuelSolutions™ Canister Features	1.2-6
1.2.1.3	Non-Packaging Support Equipment	1.2-8
1.2.2	Operational Features	1.2-8
1.2.2.1	Horizontal Canister Transfer	1.2-9
1.2.2.2	Vertical Canister Transfer	1.2-9
1.2.2.3	Canister Loading, Closure, and Opening	1.2-9
1.2.3	Contents of Packaging	1.2-9
1.2.3.1	Spent Fuel to be Transported	1.2-9
1.2.3.2	Radionuclide Inventory	1.2-12
1.2.3.3	Maximum Payload Weight	1.2-12
1.2.3.4	Maximum Decay Heat	1.2-12
1.2.3.5	Maximum Pressure Buildup	1.2-12
1.2.4	Compliance with 10CFR71	1.2-13
1.3	Appendices	1.3-1
1.3.1	General Arrangement Drawings	1.3-1
1.3.2	Product Literature	1.3-3
1.3.2.1	Borated Stainless Steel Literature	1.3-3
1.3.2.2	Electroless Nickel Plating Literature	1.3-5
1.3.3	Glossary of Terms	1.3-7
2.	**STRUCTURAL EVALUATION**	**2-1**
2.1	Structural Design	2.1-1
2.1.1	Discussion	2.1-1
2.1.1.1	Shell Assembly	2.1-1

TABLE OF CONTENTS (continued)

Section	Title	Page
	2.1.1.2 Basket Assembly	2.1-1
	2.1.1.3 Damaged Fuel Can	2.1-3
	2.1.2 Design Criteria	2.1-4
	2.1.2.1 Basic Design Criteria	2.1-4
	2.1.2.2 Load Combinations	2.1-5
	2.1.2.3 Miscellaneous Structural Failure Modes	2.1-6
2.2	Weights and Center of Gravity	2.2-1
2.3	Mechanical Properties of Materials	2.3-1
2.4	General Standards for All Packages	2.4-1
	2.4.1 Minimum Package Size	2.4-1
	2.4.2 Tamper Indicating Device	2.4-1
	2.4.3 Positive Closure	2.4-1
	2.4.4 Chemical and Galvanic Reactions	2.4-1
2.5	Lifting and Tiedown Standards	2.5-1
2.6	Normal Conditions of Transport	2.6-1
	2.6.1 Heat	2.6-1
	2.6.1.1 Summary of Pressures and Temperatures	2.6-1
	2.6.1.2 Differential Thermal Expansion	2.6-2
	2.6.1.3 Stress Calculations	2.6-6
	2.6.1.4 Fatigue Evaluation	2.6-13
	2.6.1.5 Comparison with Allowable Stresses	2.6-20
	2.6.2 Cold	2.6-29
	2.6.3 Reduced External Pressure	2.6-29
	2.6.4 Increased External Pressure	2.6-29
	2.6.5 Vibration	2.6-30
	2.6.5.1 General and LTP Spacer Plates	2.6-30
	2.6.5.2 Engagement Spacer Plate	2.6-32
	2.6.5.3 Support Tubes and Support Sleeves	2.6-33
	2.6.5.4 Guide Tubes	2.6-35

TABLE OF CONTENTS (continued)

Section	Title	Page
	2.6.5.5 Vibration Summary	2.6-38
2.6.6	Water Spray	2.6-47
2.6.7	Free Drop	2.6-47
	2.6.7.1 General and LTP Spacer Plates	2.6-47
	2.6.7.2 Engagement Spacer Plate	2.6-53
	2.6.7.3 Support Tubes	2.6-54
	2.6.7.4 Guide Tubes	2.6-56
	2.6.7.5 Canister Shell Assembly	2.6-61
	2.6.7.6 Free Drop Summary	2.6-61
2.6.8	Corner Drop	2.6-71
2.6.9	Compression	2.6-71
2.6.10	Penetration	2.6-71
2.7	Hypothetical Accident Conditions	2.7-1
2.7.1	Free Drop	2.7-1
	2.7.1.1 End Drop	2.7-2
	2.7.1.2 Side Drop	2.7-24
	2.7.1.3 Corner Drop	2.7-38
	2.7.1.4 Oblique Drop	2.7-47
2.7.2	Crush	2.7-93
2.7.3	Puncture	2.7-93
2.7.4	Thermal	2.7-93
2.7.5	Immersion - Fissile Material	2.7-94
2.7.6	Immersion - All Packages	2.7-94
2.7.7	Summary of Damage	2.7-94
2.8	Special Requirements for Irradiated Nuclear Fuel Shipments	2.8-1
2.9	Internal Pressure Test	2.9-1
2.10	Special Form	2.10-1
2.11	Fuel Rods	2.11-1
2.12	Appendices	2.12-1

TABLE OF CONTENTS (continued)

Section	Title	Page
2.12.1	General and LTP Spacer Plate Tributary Weights	2.12-1
2.12.2	Free Drop Equivalent Static Design Loads	2.12-9
2.12.2.1	W74 Canister Frequency Analysis	2.12-9
2.12.2.2	Equivalent Static Accelerations	2.12-13
2.12.3	General and LTP Spacer Plate Stress Evaluation Points	2.12-15
2.12.4	Finite Element Model Descriptions	2.12-17
2.12.4.1	General and LTP Spacer Plate Models	2.12-17
2.12.4.2	Engagements Spacer Plate Finite Element Models	2.12-22
2.12.4.3	Guide Tube Half-Symmetry Periodic Model	2.12-28
2.12.4.4	Canister Top Shield Plug Model	2.12-29
2.12.4.5	Canister Shell Axisymmetric Finite Element Model	2.12-31
2.12.4.6	Canister Shell Half-Symmetry Finite Element Model	2.12-32
2.12.5	Canister Shell Stress Evaluation Points	2.12-53
3.	**THERMAL EVALUATION**	**3-1**
3.1	Discussion	3.1-1
3.1.1	Design Features	3.1-1
3.1.1.1	W74 Canister	3.1-2
3.1.1.2	Transportation Cask	3.1-3
3.1.2	Design Basis Thermal Load Conditions	3.1-4
3.1.3	Design Basis Axial Heat Generation Profile	3.1-5
3.1.3.1	Development of the Design Basis Axial Heat Generation Profile	3.1-6
3.1.3.2	Application of Axial Heat Profiles for Canister Analysis	3.1-7
3.1.3.3	Compliance with Transportation Cask Thermal Requirements	3.1-8
3.1.4	Temperature Summary	3.1-8
3.1.5	Transportation Cask Internal Pressure Summary	3.1-9
3.2	Summary of Thermal Properties of Materials	3.2-1
3.2.1	W74 Canister	3.2-1
3.2.2	Big Rock Point Fuel	3.2-2

TABLE OF CONTENTS (continued)

Section	Title	Page
3.3	Technical Specification of Components	3.3-1
3.3.1	W74 Canister	3.3-1
3.3.2	Fuel Cladding Allowable Temperatures	3.3-2
3.4	Thermal Evaluation for Normal Conditions of Transport	3.4-1
3.4.1	Thermal Models	3.4-1
3.4.1.1	Analytical Thermal Models	3.4-1
3.4.1.2	Test Thermal Model	3.4-7
3.4.2	Maximum Temperatures	3.4-7
3.4.3	Minimum Temperatures	3.4-9
3.4.4	Maximum Internal Pressures	3.4-9
3.4.4.1	Fuel Rod Fill Gas	3.4-11
3.4.4.2	Fuel Rod Fission Gas Generation	3.4-11
3.4.4.3	Transportation Cask MNOP	3.4-12
3.4.5	Maximum Thermal Stresses	3.4-13
3.4.6	Evaluation of Package Performance for Normal Conditions of Transport	3.4-13
3.5	Thermal Evaluation for Hypothetical Accident Conditions	3.5-1
3.5.1	Thermal Model	3.5-1
3.5.1.1	Analytical Thermal Model	3.5-1
3.5.1.2	Test Thermal Model	3.5-2
3.5.2	Package Conditions and Environment	3.5-2
3.5.3	Package Temperatures	3.5-3
3.5.4	Maximum Internal Pressures	3.5-4
3.5.5	Maximum Thermal Stresses	3.5-4
3.5.6	Evaluation of Package Performance for Hypothetical Accident Conditions	3.5-5
3.6	Appendices	3.6-1
3.6.1	Canister Internal Convection	3.6-1
3.6.2	Other Modes of Heat Transfer	3.6-4

TABLE OF CONTENTS (continued)

Section	Title	Page
3.6.3	Impact Of Fission Gas Release On Thermal Performance	3.6-6
3.6.4	Big Rock Point Mixed-Oxide (MOX) Fuel	3.6-9
3.6.4.1	Heat Generation of BRP MOX Fuel	3.6-9
3.6.4.2	Axial Heat Generation Profile of BRP MOX Fuel	3.6-9
3.6.4.3	Effective Thermal Conductivity of BRP MOX Fuel	3.6-10
3.6.4.4	Allowable Cladding Temperature for BRP MOX Fuel	3.6-10
3.6.4.5	Canister Internal Pressure for BRP MOX Fuel	3.6-11
3.6.4.6	Thermal Summary for BRP MOX Fuel	3.6-11
3.6.5	Big Rock Point Damaged Fuel	3.6-11
3.6.5.1	Heat Generation of BRP Damaged Fuel	3.6-12
3.6.5.2	Axial Heat Generation Profile of BRP Damaged Fuel	3.6-12
3.6.5.3	Effective Thermal Conductivity of BRP Damaged Fuel	3.6-12
3.6.5.4	Allowable Cladding Temperature for BRP Damaged Fuel	3.6-14
3.6.5.5	Estimated Cladding Temperature for BRP Damaged Fuel	3.6-14
3.6.5.6	Estimated Cladding Temperature for BRP Fuel Rubble	3.6-16
3.6.5.7	Canister Internal Pressure for BRP Damaged Fuel	3.6-16
3.6.5.8	Thermal Summary for BRP Damaged Fuel Assemblies	3.6-17
3.6.6	Big Rock Point Partial Fuel Assemblies	3.6-17
3.6.6.1	Maximum Canister Thermal Rating for BRP Partial Fuel Assemblies	3.6-17
3.6.6.2	Effective Thermal Conductivity of BRP Partial Fuel Assemblies	3.6-17
3.6.6.3	Thermal Summary for BRP Partial Fuel Assemblies	3.6-18
3.6.7	Computer Code Descriptions	3.6-18
3.6.7.1	Thermal Desktop® Computer Code	3.6-18
3.6.7.2	SINDA/FLUINT® Computer Code	3.6-18
3.6.7.3	RadCAD® Computer Code	3.6-19
4. CONTAINMENT		**4-1**
4.1	Description of Containment System	4.1-1

TABLE OF CONTENTS (continued)

Section | Title | Page

4.1.1 Containment Boundary 4.1-1
4.1.2 Codes and Standards 4.1-1
4.1.3 Special Requirements for Damaged Spent Nuclear Fuel 4.1-1
4.2 Containment Under Normal Conditions of Transport 4.2-1
4.2.1 Pressurization of Containment Vessel 4.2-1
4.2.2 Containment Criteria 4.2-1
4.2.3 Compliance with Containment Criteria 4.2-1
4.3 Containment Under Hypothetical Accident Conditions 4.3-1
4.3.1 Pressurization of Containment Vessel 4.3-1
4.3.2 Containment Criteria 4.3-1
4.3.3 Compliance with Containment Criteria 4.3-1

5. SHIELDING EVALUATION 5-1
5.1 Discussion and Results 5.1-1
5.1.1 FuelSolutions™ TS125 Transportation Cask Shielding Design Features 5.1-1
5.1.2 FuelSolutions™ W74 Canister Shielding Design Features 5.1-1
5.1.3 Shielding Results 5.1-2
5.2 Source Specification 5.2-1
5.2.1 FuelSolutions™ Generic Decay Library 5.2-1
5.2.2 Gamma Source Terms 5.2-2
5.2.2.1 Active Fuel Primary Gamma Sources 5.2-2
5.2.2.2 End Fitting and Plena Region Gamma Sources 5.2-3
5.2.2.3 Secondary Gamma Sources 5.2-4
5.2.2.4 Axial Distribution of Gamma Sources 5.2-4
5.2.3 Neutron Source Terms 5.2-5
5.2.3.1 Neutron Source Strengths 5.2-5
5.2.3.2 Neutron Energy Spectrum 5.2-5
5.2.3.3 Axial Neutron Distribution 5.2-6
5.3 Model Specification 5.3-1

TABLE OF CONTENTS (continued)

Section Title Page

5.3.1 Description of Radial and Axial Shielding Configuration 5.3-1
5.3.1.1 Overview 5.3-1
5.3.1.2 Treatment of Voids, Streaming Paths, and Other Geometry Irregularities 5.3-1
5.3.1.3 Differences Between Normal and Accident Models 5.3-2
5.3.1.4 Dose Point Locations 5.3-2
5.3.1.5 TS125 Cask Body Geometry 5.3-3
5.3.1.6 W74 Canister Geometry 5.3-3
5.3.2 Shield Regional Densities 5.3-5
5.3.2.1 FuelSolutions™ W125 Transportation Cask Shield Regional Densities 5.3-5
5.3.2.2 FuelSolutions™ W74 Canister Shield Regional Densities 5.3-5
5.4 Shielding Evaluation 5.4-1
5.4.1 Methodology 5.4-1
5.4.2 Results 5.4-2
5.5 Supplemental Data 5.5-1
5.5.1 BRP Mixed-Oxide (MOX) Fuel Assembly Qualification 5.5-1
5.5.2 BRP Partial Fuel Assembly Qualification 5.5-3
5.5.3 BRP Damaged Fuel Assembly Qualification 5.5-3

6. CRITICALITY EVALUATION 6-1
6.1 Discussion and Results 6.1-1
6.2 Package Fuel Loading 6.2-1
6.3 Model Specification 6.3-1
6.3.1 Description of Calculational Model 6.3-1
6.3.1.1 Hypothetical Accident Conditions 6.3-5
6.3.1.2 Normal Conditions of Transport 6.3-8
6.3.1.3 Criticality Models for MOX, Partial, and Damaged BRP Fuel 6.3-9
6.3.2 Package Regional Densities 6.3-11
6.4 Criticality Evaluation 6.4-1

TABLE OF CONTENTS (continued)

Section	Title	Page
6.4.1	Calculational Method	6.4-1
6.4.2	Fuel Loading Optimization	6.4-1
6.4.2.1	Package Array	6.4-1
6.4.2.2	Single Package	6.4-7
6.4.3	Criticality Results	6.4-8
6.5	Criticality Benchmark Experiments	6.5-1
6.6	Supplemental Analyses	6.6-1
6.6.1	Big Rock Point Mixed-Oxide Fuel Assembly Criticality Evaluation	6.6-1
6.6.1.1	MOX Fuel Criticality Analyses	6.6-1
6.6.1.2	MOX Fuel Criticality Benchmarks	6.6-6
6.6.2	Big Rock Point Partial Fuel Assembly Criticality Evaluation	6.6-10
6.6.2.1	Partial Assemblies with Missing Corner Rods	6.6-11
6.6.2.2	Partial Assemblies with Missing Array-Interior or Array-Edge Rods	6.6-12
6.6.3	Big Rock Point Damaged Fuel Assembly Criticality Evaluation	6.6-16
6.6.3.1	W74 Canister Model for the Damaged Assembly Analyses	6.6-16
6.6.3.2	Damaged Fuel Can Contents Model Description	6.6-17
6.6.3.3	Damaged Assembly Criticality Analysis Results	6.6-19
6.6.3.4	Damaged Fuel Can Preferential Flooding Analysis	6.6-24
6.6.3.5	Damaged BRP MOX Assembly Analyses	6.6-24
6.6.3.6	Other Allowable Damaged Fuel Can Contents	6.6-27
6.6.4	The W74 Canister Inside the TS125 Transportation Cask	6.6-28
7.	**OPERATING PROCEDURES**	**7-1**
7.1	Procedures for Loading the Cask in the Spent Fuel Pool	7.1-1
7.1.1	Preparation of an Empty Canister for Fuel Loading	7.1-1
7.1.2	Installing an Empty Canister into the Transportation Cask	7.1-1
7.1.3	Load Fuel into the Canister	7.1-1
7.1.4	Drain and Backfill Canister with Helium	7.1-2
7.2	Procedures for Unloading Package	7.2-1

TABLE OF CONTENTS (continued)

Section	Title	Page
7.3	Preparation of Empty Package for Transport	7.3-1
7.4	Appendix	7.4-1
8.	**ACCEPTANCE TESTS AND MAINTENANCE PROGRAM**	**8-1**

LIST OF TABLES

Tables	Title	Page
Table 1.0-1	FuelSolutions™ Transportation SAR Regulatory Compliance Cross-Reference Matrix (13 pages)	1-8
Table 1.2-1	Principal Characteristics of the FuelSolutions™ W74 Canister	1.2-14
Table 1.2-2	Matrix of FuelSolutions™ W74 Canister Configurations	1.2-15
Table 1.2-3	FuelSolutions™ W74 Canister Design Criteria Summary (3 pages)	1.2-16
Table 1.2-4	FuelSolutions™ W74 Canister SNF Assembly Acceptance Criteria for Transport (6 pages)	1.2-19
Table 1.2-5	FuelSolutions™ W74 Canister SNF Fuel Assembly Classes Acceptable for Transport	1.2-25
Table 1.2-6	FuelSolutions™ W74 Canister UO_2 SNF Fuel Assemblies Acceptable for Transport(1)	1.2-26
Table 1.2-7	FuelSolutions™ W74 Canister MOX SNF Assemblies Acceptable for Transport(1)	1.2-27
Table 2.1-1	FuelSolutions™ W74 Canister Minimum Design Margins for NCT Loading Conditions	2.1-9
Table 2.1-2	FuelSolutions™ W74 Canister Minimum Design Margins for HAC Loading Conditions	2.1-10
Table 2.1-3	Summary of FuelSolutions™ W74 Canister Component Functions and Design Codes	2.1-11
Table 2.1-4	Canister Shell Allowable Stress Criteria	2.1-12
Table 2.1-5	Canister Basket Allowable Stress Criteria	2.1-12
Table 2.1-6	Summary of NCT Load Combinations	2.1-13
Table 2.1-7	Summary of HAC Load Combinations	2.1-13
Table 2.2-1	W74 Canister Weights and Centers of Gravity	2.2-2
Table 2.3-1	FuelSolutions™ W74M Canister Materials Summary	2.3-3
Table 2.3-2	FuelSolutions™ W74T Canister Material Summary	2.3-4
Table 2.3-3	Type 316 Stainless Steel Material Properties	2.3-5
Table 2.3-4	Type 316 Stainless Steel Plastic Material Properties	2.3-5
Table 2.3-5	Type 304 Stainless Steel Material Properties	2.3-6
Table 2.3-6	Type XM-19 Stainless Steel Material Properties	2.3-7
Table 2.3-7	ASTM A36 Carbon Steel Material Properties	2.3-8
Table 2.3-8	A514, Grades F or P Carbon Steel Material Properties	2.3-9
Table 2.3-9	SA-517, Grade F or P Carbon Steel Material Properties	2.3-10
Table 2.3-10	Neutron Absorber Material Properties	2.3-11
Table 2.3-11	A516, Grades 55 and 60 Carbon Steel Material Properties	2.3-12
Table 2.6-1	Summary of W74 Canister Temperatures	2.6-21
Table 2.6-2	W74 General Spacer Plate Stress Intensities (20 Highest Values) - NCT Cold Environment Thermal Loading	2.6-22
Table 2.6-3	W74 LTP Spacer Plate Stress Intensities (20 Highest Values) - NCT Cold Environment Thermal Loading	2.6-23
Table 2.6-4	Summary of W74 NCT Thermal Stress Design Margins	2.6-24
Table 2.6-5	Summary of W74 Canister NCT Vibration Design Margins	2.6-40
Table 2.6-6	W74 Guide Tube Longitudinal Seam Weld Stresses due to NCT Vibration Loading (Horizontal Panel)	2.6-41

LIST OF TABLES (continued)

Table	Title	Page
Table 2.6-7	W74 Guide Tube Longitudinal Seam Weld Stresses due to NCT Vibration Loading (Vertical Panel)	2.6-42
Table 2.6-8	Summary of W74 Canister NCT Free Drop Design Margins	2.6-62
Table 2.6-9	W74 General Spacer Plate Allowable Buckling Stresses for NCT Conditions	2.6-63
Table 2.6-10	W74 LTP Spacer Plate Allowable Buckling Stresses for NCT Conditions	2.6-64
Table 2.6-11	W74 Spacer Plate NCT Side Drop Ligament Stresses and Buckling Interaction Ratios	2.6-65
Table 2.7-1	Summary of W74 Canister Basket Assembly HAC End Drop Design Margins	2.7-20
Table 2.7-2	W74 Canister Shell HAC End Drop Stress Analysis Results	2.7-21
Table 2.7-3	W74 Spacer Plate 60*g* Side Drop Elastic Stress Analysis Results	2.7-33
Table 2.7-4	Summary of W74 Canister Basket Assembly HAC Side Drop Design Margins	2.7-34
Table 2.7-5	Summary of W74 Canister HAC Corner Drop Design Margins	2.7-45
Table 2.7-6	W74 Canister General and LTP Spacer Plate Maximum Stress Intensities for 36*g* Transverse Loading	2.7-75
Table 2.7-7	W74 Canister General and LTP Spacer Plate Maximum Stresses for HAC Oblique Drop Secondary Impact	2.7-75
Table 2.7-8	W74 General Spacer Plate Allowable Buckling Stresses	2.7-76
Table 2.7-9	W74 LTP Spacer Plate Allowable Buckling Stresses	2.7-77
Table 2.7-10	W74 General Spacer Plate Buckling Interaction Ratios for HAC Slapdown Impact Loading without Thermal	2.7-78
Table 2.7-11	W74 General Spacer Plate Buckling Interaction Ratios for Combined HAC Slapdown Impact and NCT Thermal Loading	2.7-79
Table 2.7-12	W74 LTP Spacer Plate Buckling Interaction Ratios for HAC Slapdown Impact Loading without Thermal	2.7-80
Table 2.7-13	W74 LTP Spacer Plate Buckling Interaction Ratios for Combined HAC Slapdown Impact and NCT Thermal Loading	2.7-81
Table 2.7-14	Guide Tube Neutron Absorber Sheet Retainer Weld Shear Stresses – HAC Oblique Drop Slapdown Impact	2.7-82
Table 2.7-15	W74 Canister Shell Assembly HAC Oblique Drop Slapdown Impact Stress Analysis Results	2.7-83
Table 2.7-16	Summary of W74 Canister HAC Oblique Drop Design Margins	2.7-84
Table 2.12-1	W74M Spacer Plate Tributary Weights – Uniform Fuel Loading	2.12-4
Table 2.12-2	W74T Spacer Plate Tributary Weights – Uniform Fuel Loading	2.12-5
Table 2.12-3	BRP Fuel Grid Spacer Positions and Tributary Weights	2.12-6
Table 2.12-4	W74M Spacer Plate Tributary Weights – Concentrated Fuel Loading	2.12-7
Table 2.12-5	W74T Spacer Plate Tributary Weights – Concentrated Fuel Loading	2.12-8
Table 2.12-6	W74 Canister Equivalent Static Free Drop G-Loads	2.12-14
Table 3.1-1	Transportation Design Basis Thermal Conditions	3.1-11
Table 3.1-2	W74 Canister Design-Basis Axial Heat Profile	3.1-12
Table 3.1-3	W74 Canister Maximum Thermal Ratings for Transportation	3.1-13
Table 3.1-4	W74 Canister Thermal Ratings vs. SNF Burnup	3.1-13
Table 3.1-5	Transportation Cask Internal Pressures with Loaded W74 Canister	3.1-14
Table 3.2-1	W74 Canister Homogenous Material Properties (2 pages)	3.2-4
Table 3.2-2	W74 Canister Surface Emissivities	3.2-6
Table 3.2-3	W74 Canister Material Properties, Fluids	3.2-7

LIST OF TABLES (continued)

Table	Title	Page
Table 3.3-1	W74 Canister Component Allowable Temperatures	3.3-5
Table 3.4-1	FuelSolutions™ W74 Canister Maximum System Temperatures for NCT	3.4-14
Table 3.4-2	Transportation Package NCT Internal Pressures	3.4-15
Table 3.4-3	W74 Canister SNF Gas	3.4-16
Table 3.4-4	W74 Canister Free Volume and MNOP(1)	3.4-17
Table 3.5-1	W74/TS125 System Temperature For HAC Fire	3.5-6
Table 3.5-2	W74 Canister and Transportation Cask Internal Pressures for HAC Fire Event	3.5-7
Table 3.6-1	FuelSolutions™ W74 Canister Maximum System Temperatures With and Without Fission Gas Release	3.6-21
Table 3.6-2	W74 Damaged Fuel Effective Conductivity	3.6-22
Table 5.1-1	Summary of W125/W74 Maximum Dose Rates	5.1-3
Table 5.1-2	W74 Canister Shielding Design Features	5.1-4
Table 5.2-1	BWR Source Term Calculation Input Parameters	5.2-8
Table 5.2-2	W74 UO_2 Fuel Gamma Sources	5.2-9
Table 5.2-3	W74 Assembly Hardware Gamma Source Strengths	5.2-10
Table 5.2-4	BWR Fuel Axial Gamma Profiles	5.2-11
Table 5.2-5	W74 Normalized Neutron Source Spectrum	5.2-12
Table 5.2-6	W74 Axial Neutron Source Profiles	5.2-13
Table 5.3-1	Roadmap to W74 Shielding Models	5.3-7
Table 5.3-2	W74 Canister Component Dimensions	5.3-8
Table 5.3-3	Canister Interior Source Zone Dimensions (in.)	5.3-9
Table 5.3-4	Raw Material Atom Densities	5.3-10
Table 5.3-5	W74 Active Fuel Region Densities	5.3-11
Table 5.3-6	W74 Plenum Region Densities	5.3-12
Table 5.3-7	W74 Bottom End Densities	5.3-13
Table 5.3-8	W74 Top End Densities	5.3-14
Table 5.3-9	W74 "Center" Region Densities(1)	5.3-15
Table 5.4-1	W74 Normal Condition Results (3 pages)	5.4-4
Table 5.4-2	W74 Accident Condition Results	5.4-7
Table 5.5-1	ORIGEN 2.1 Data for BRP MOX Fuel Assemblies	5.5-5
Table 5.5-2	BRP MOX Fuel Gamma Source Strengths	5.5-6
Table 5.5-3	BRP MOX Fuel Gamma Source Strength Comparison	5.5-7
Table 5.5-4	BRP MOX Assembly Total Neutron Source Strengths	5.5-8
Table 5.5-5	W74 MOX Fuel Normal Condition Results (3 pages)	5.5-9
Table 5.5-6	W74 MOX Fuel Accident Condition Results	5.5-12
Table 6.1-1	W74 Canister Fuel Specification for Big Rock Point	6.1-3
Table 6.2-1	Specific Fuel Assembly Parameters	6.2-3
Table 6.3-1	Worst-Case Material and Fabrication Tolerances for the FuelSolutions™ W74 Canister	6.3-13
Table 6.3-2	W74 Basket Model Differences Between Intact, Partial, MOX, and Damaged BRP Assembly Criticality Analyses	6.3-14
Table 6.3-3	UO_2 Number Densities as a Function of Enrichment	6.3-15
Table 6.3-4	Water Number Densities as a Function of Density	6.3-16
Table 6.3-5	Zircaloy-4 Number Densities	6.3-17
Table 6.3-6	304 Stainless Steel Number Densities	6.3-17

LIST OF TABLES (continued)

Table	Title	Page
Table 6.3-7	Borated Stainless Steel Number Densities (1.0 w/o natural boron)	6.3-18
Table 6.3-8	Borated Stainless Steel Number Densities (1.25 w/o natural boron)	6.3-18
Table 6.3-9	316 Stainless Steel Number Densities	6.3-19
Table 6.3-10	517 P Carbon Steel Number Densities	6.3-19
Table 6.3-11	XM-19 Stainless Steel Number Densities	6.3-20
Table 6.3-12	Depleted Uranium Number Densities	6.3-20
Table 6.3-13	Solid Neutron Shield Number Densities	6.3-21
Table 6.4-1	MCNP Results for the Canister Design Case Studies	6.4-10
Table 6.4-2	Material and Fabrication Tolerance Results for the FuelSolutions™ W74 Canister	6.4-11
Table 6.4-3	Optimum Interspersed Moderator Case Results for the FuelSolutions™ W74 Canister	6.4-12
Table 6.4-4	Optimum Interior Moderator Case Results for the FuelSolutions™ W74 Canister	6.4-13
Table 6.4-5	MCNP Results for the FuelSolutions™ W74 Canister and Big Rock Point Fuel Assemblies with Variable Fuel Rod Enrichments	6.4-14
Table 6.4-6	MCNP Results for the FuelSolutions™ W74 Canister and Big Rock Point Fuel Assemblies with Lattice Average Fuel Rod Enrichments	6.4-15
Table 6.4-7	Multiple-Package Array, Hypothetical Accident Condition Results to Determine the Bounding Fuel Assembly Configuration (4.1% Enriched Fuel)	6.4-16
Table 6.4-8	Big Rock Point Fuel Assembly USL Value Ranges	6.4-16
Table 6.4-9	Multiple-Package Array, Normal Operating Condition Results	6.4-17
Table 6.4-10	MCNP Results for the Single-Package Models	6.4-17
Table 6.5-1	Benchmark Critical Experiments (2 Pages)	6.5-3
Table 6.6-1	Uranium Isotope Atom Densities for UO_2 Fuel Rods in BRP MOX Assemblies	6.6-31
Table 6.6-2	BRP Assembly MOX Fuel Pin Isotope Densities (atom/barn-cm)	6.6-31
Table 6.6-3	MCNP Calculated Keff Values for W74 Baskets Fully Loaded with BRP MOX Fuel (Full Water Density)	6.6-32
Table 6.6-4	MCNP Calculated K_{eff} for MOX Fuel vs. W74 Interior Water Density (G-Pu Fuel Assemblies)	6.6-33
Table 6.6-5	W74 Canister MOX Fuel Specifications	6.6-34
Table 6.6-6	MOX Fuel Benchmark Critical Experiments	6.6-35
Table 6.6-7	Upper Sub-Critical Limit Formulas for the MOX Only, UO_2 Only, and MOX + UO_2 Sets of Critical Experiments	6.6-36
Table 6.6-8	Parameter Ranges Covered by Critical Experiments and BRP MOX Fuel Assemblies	6.6-37
Table 6.6-9	Calculated K_{eff} Values for BRP Assemblies with Missing Array Corner Rods	6.6-38
Table 6.6-10	Calculated K_{eff} vs. Fuel Rod Pitch for 4.1% Enriched GE 9x9 BRP Assembly Fuel Rods (Single Assembly with Full Water Reflection)	6.6-38
Table 6.6-11	Calculated K_{eff} vs. Fuel Rod Pitch for 4.1% Enriched Siemens 11x11 BRP Assembly Fuel Rods (Single Assembly with Full Water Reflection)	6.6-39
Table 6.6-12	Calculated K_{eff} for BRP Partial Assemblies at Maximum Allowable Enrichment (Optimum Pitch[1] Fuel Rod Arrays Inside the W74 Canister)	6.6-39
Table 6.6-13	Physical Parameters and USL Values for the Optimum BRP Fuel Rod Arrays	6.6-40

LIST OF TABLES (continued)

Table	Title	Page
Table 6.6-14	Calculated K_{eff} Values for a W74 Canister w/ Eight Damaged Fuel Cans Containing a Square Array of 0.471-inch Diameter Fuel Cylinders (Guide Tubes Contain Partial 9x9 BRP Assembly Configurations)	6.6-40
Table 6.6-15	Calculated K_{eff} Values for a W74 Canister w/ Eight Damaged Fuel Cans Containing a Square Array of 0.3715-inch Diameter Fuel Cylinders (Guide Tubes Contain Partial 9x9 BRP Assembly Configurations)	6.6-41
Table 6.6-16	Calculated K_{eff} Values for a W74 Canister w/ Eight Damaged Fuel Cans Containing a Hexagonal Array of 0.471-inch Diameter Fuel Cylinders (Guide Tubes Contain Partial 9x9 BRP Assembly Configurations)	6.6-41
Table 6.6-17	Calculated K_{eff} Values for a W74 Canister w/ Eight Damaged Fuel Cans Containing a Hexagonal Array of 0.3715-inch Diameter Fuel Cylinders (Guide Tubes Contain Partial 9x9 BRP Assembly Configurations)	6.6-42
Table 6.6-18	Calculated K_{eff} Values for a W74 Canister w/ Eight Damaged Fuel Cans Containing a Hexagonal Array of 0.9 cm Diameter Fuel Spheres (Guide Tubes Contain Partial 9x9 BRP Assembly Configurations)	6.6-42
Table 6.6-19	Calculated K_{eff} Values for a W74 Canister w/ Eight Damaged Fuel Cans Containing a Square Array of 0.3715-inch Diameter Fuel Cylinders (Guide Tubes Contain Intact 11x11 BRP Assembly Configurations)	6.6-43
Table 6.6-20	W74 Damaged Assembly 10CFR71 Criticality Margin Calculation (0.655-inch Pitch Square Array of 0.3715-inch Diameter Fuel Cylinders in All Damaged Fuel Cans)	6.6-43
Table 6.6-21	H-to-^{235}U Ratio vs. Array Dimension for Various UO_2 Fuel Rod Diameters and MOX Fuel Rod Material Compositions[1]	6.6-44
Table 6.6-22	Final k_{eff} vs. Fuel Cylinder Diameter and H-to-^{235}U Ratio[1]	6.6-45
Table 6.6-23	Final k_{eff} vs. H-to-^{235}U Ratio for Various Fuel Sphere Diameters	6.6-46
Table 6.6-24	Final k_{eff} vs. Particle Diameter for UO_2 Fuel Cylinders and Spheres (at optimum H-to-^{235}U ratio)	6.6-46
Table 6.6-25	Transportation Cask Comparison Case Results for the FuelSolutions™ W74 Canister	6.6-47
Table 6.6-26	MCNP Results for the TS125 Cask Single-Package Models	6.6-48
Table 7.1-1	Helium Backfill Gas Quantities for the FuelSolutions™ W74 Canister	7.1-3

This page intentionally left blank.

LIST OF FIGURES

Figures **Title** **Page**

Figure 1.0-1 - FuelSolutions™ Spent Fuel Management System Elements 1-6
Figure 1.0-2 - FuelSolutions™ Transportation Package Certification Application Approach 1-7
Figure 1.2-1 - FuelSolutions™ Spent Fuel Management System 1.2-28
Figure 1.2-2 - Expanded View of FuelSolutions™ W74 Canister 1.2-29
Figure 2.1-1 - FuelSolutions™ W74 Canister Support Tube Assembly Detail 2.1-14
Figure 2.1-2 - FuelSolutions™ W74 Damaged Fuel Can 2.1-15
Figure 2.2-1 - FuelSolutions™ W74 Canister Center of Gravity Diagram 2.2-3
Figure 2.6-1 - W74 Canister Support Tube and End Spacer Plate Curvature Due to Lateral Thermal Gradients 2.6-25
Figure 2.6-2 - W74 General Spacer Plate NCT Cold Environment Thermal Gradient 2.6-26
Figure 2.6-3 - W74 LTP Spacer Plate NCT Cold Environment Thermal Gradient 2.6-27
Figure 2.6-4 - W74 Canister Engagement Spacer Plate NCT Cold Environment Thermal Gradient 2.6-28
Figure 2.6-5 - W74 Guide Tube NCT Vibration S.I. Contour Plot (Middle Fiber) 2.6-43
Figure 2.6-6 - W74 Guide Tube NCT Vibration S.I. Contour Plot (Top Fiber) 2.6-44
Figure 2.6-7 - W74 Guide Tube NCT Vibration S.I. Contour Plot (Bottom Fiber) 2.6-45
Figure 2.6-8 - W74 Spacer Plate NCT Free Drop Loading Diagram 2.6-66
Figure 2.6-9 - W74 Guide Tube S.I. Contour Plot (Middle Fiber) - 15*g* NCT Side Drop, Uniform Fuel Loading 2.6-67
Figure 2.6-10 - W74 Guide Tube S.I. Contour Plot (Top Fiber) - 15*g* NCT Side Drop, Uniform Fuel Loading 2.6-68
Figure 2.6-11 - W74 Guide Tube S.I. Contour Plot (Bottom Fiber) - 15*g* NCT Side Drop, Uniform Fuel Loading 2.6-69
Figure 2.7-1 - W74 Canister Guide Tube HAC End Drop Buckling Evaluation Boundary Conditions 2.7-22
Figure 2.7-2 - W74 Canister General and LTP Spacer Plate HAC Side Drop Impact Orientations Evaluated 2.7-35
Figure 2.7-3 - W74 Canister Engagement Spacer Plate HAC Side Drop Impact Orientations Evaluated 2.7-36
Figure 2.7-4 - W74 Guide Tube S.I. Contour Plot (Middle Fiber) - 62*g* Slapdown, Uniform SNF Loading, Elastic Analysis 2.7-85
Figure 2.7-5 - W74 Guide Tube S.I. Contour Plot (Top Fiber) - 62*g* Slapdown, Uniform SNF Loading, Elastic Analysis 2.7-86
Figure 2.7-6 - W74 Guide Tube S.I. Contour Plot (Bottom Fiber) - 62*g* Slapdown, Uniform SNF Loading, Elastic Analysis 2.7-87
Figure 2.7-7 - W74 Guide Tube S.I. Contour Plot (Middle Fiber) - 64.5*g* Slapdown Load, Concentrated SNF Loading, Plastic Analysis 2.7-88
Figure 2.7-8 - W74 Guide Tube S.I. Contour Plot (Top Fiber) - 64.5*g* Slapdown Load, Concentrated SNF Loading, Plastic Analysis 2.7-89
Figure 2.7-9 - W74 Guide Tube S.I. Contour Plot (Bottom Fiber) - 64.5*g* Slapdown Load, Concentrated SNF Loading, Plastic Analysis 2.7-90
Figure 2.7-10 - W74 Guide Tube Permanent Deformation Resulting from HAC Slapdown Impact Loading 2.7-91
Figure 2.7-11 - Canister Shell Stress Intensity Contour Plot for 87*g* HAC Slapdown Load 2.7-92
Figure 2.12-1 - W74 Canister General and LTP Spacer Plate Stress Evaluation Points 2.12-16

LIST OF FIGURES (continued)

Figure **Title** **Page**

Figure 2.12-2 - W74 Canister General and LTP Spacer Plate Plane-Stress Finite Element Model 2.12-35
Figure 2.12-3 - W74 Canister General and LTP Spacer Plate Loading Diagram 2.12-36
Figure 2.12-4 - W74 General Spacer Plate Full Multi-Span Finite Element Model 2.12-37
Figure 2.12-5 - W74 General Spacer Plate Buckling Shell Finite Element Model 2.12-38
Figure 2.12-6 - W74 Canister Engagement Spacer Plate Half-Symmetry Plane-Stress Finite Element Model 2.12-39
Figure 2.12-7 - W74 Canister Engagement Spacer Plate Full Plane-Stress Finite Element Model 2.12-40
Figure 2.12-8 - W74 Canister Engagement Spacer Plate Solid Quarter-Symmetry Modal Analysis Model 2.12-41
Figure 2.12-9 - W74 Canister Engagement Spacer Plate HAC End Drop Modal Analysis Mass Distribution 2.12-42
Figure 2.12-10 - W74 Canister Engagement Spacer Plate HAC End Drop Solid Quarter-Symmetry Model Boundary Conditions 2.12-43
Figure 2.12-11 - W74 Canister Engagement Spacer Plate HAC End Drop Solid Quarter-Symmetry Model Pressure Loading 2.12-44
Figure 2.12-12 - W74 Canister Guide Tube Finite Element Model 2.12-45
Figure 2.12-13 - W74 Canister Top Shield Plug Quarter Symmetry Model 2.12-46
Figure 2.12-14 - W74 Canister Top Shield Plug Quarter Symmetry Model Adjusted Density Regions 2.12-47
Figure 2.12-15 - Bounding Canister Shell Assembly Axisymmetric Finite Element Model 2.12-48
Figure 2.12-16 - Canister Shell Half-Symmetry Finite Element Model 2.12-49
Figure 2.12-17 - Canister Shell Assembly Half-Symmetry Finite Element Model, Shell Assembly Mesh 2.12-50
Figure 2.12-18 - Canister Shell Assembly Half-Symmetry Finite Element Model - Spacer Plate Mesh and Loading 2.12-51
Figure 2.12—19 - Canister Shell Axisymmetric Model Stress Evaluation Locations - Top and Bottom End Regions 2.12-54
Figure 2.12—20 - Canister Shell Axisymmetric Model Stress Evaluation Locations - Cavity Region 2.12-55
Figure 3.1-1 - Design Basis Axial Heat Profile for W74 Canister Analysis 3.1-15
Figure 3.1-2 - Max. Peaking Factor vs. Burnup for BWR Fuel 3.1-15
Figure 3.4-1 - FuelSolutions™ W74M Canister Thermal Submodel Layout 3.4-18
Figure 3.4-2 - Node Layout for W74 Canister Bottom End 3.4-19
Figure 3.4-3 - Typical Node Layout Between W74 Spacer Plates 3.4-20
Figure 3.4-4 - Node Layout for W74 Canister Fuel Load Configuration 3.4-21
Figure 3.4-5 - Typical Node Layout for W74 Spacer Plate 3.4-22
Figure 3.4-6 - Isometric View of Node Layout Between Typical Set of W74 Spacer Plates 3.4-23
Figure 3.4-7 - Node Layout for W74 Canister Mid-Length Section 3.4-24
Figure 3.4-8 - Node Layout for W74 Top End 3.4-25
Figure 3.4-9 - Assumed Flow Pattern within Horizontal Canister 3.4-26
Figure 3.4-10 - Sensitivity of W74 Canister and TS125 Transportation Cask Components to Heat Load 3.4-27
Figure 3.4-11 - W74/TS125 Axial Temperature Distribution; NCT Hot (100°F), 180° Rotation From Bottom 3.4-28

LIST OF FIGURES (continued)

Figure	Title	Page
Figure 3.4-12	W74/TS125 Cask Axial Temperature Distribution; NCT Hot (100°F), 15° Rotation From Bottom	3.4-29
Figure 3.4-13	W74/TS125 Cask Radial Temperature Distribution; NCT Hot (100°F), 15° Rotation From Bottom	3.4-30
Figure 3.4-14	W74/TS125 Cask Axial Temperature Distribution; NCT Cold (-20°F), 15° Rotation From Bottom	3.4-31
Figure 3.4-15	W74/TS125 Cask Radial Temperature Distribution; NCT Cold (-20°F), 15° Rotation From Bottom	3.4-32
Figure 3.4-16	Hottest W74 Stainless Steel Spacer Plate Temperature Distribution, NCT Hot (100°F)	3.4-33
Figure 3.4-17	Hottest W74 Carbon Steel Spacer Plate Temperature Distribution, NCT Hot (100°F)	3.4-34
Figure 3.4-18	W74 Engagement Plate Temperature Distribution, NCT Hot (100°F)	3.4-35
Figure 3.4-19	Hottest W74 Stainless Steel Spacer Plate Temperature Distribution, NCT Cold (-20°F)	3.4-36
Figure 3.4-20	Hottest W74 Carbon Steel Spacer Plate Temperature Distribution, NCT Cold (-20°F)	3.4-37
Figure 3.4-21	W74 Engagement Plate Temperature Distribution, NCT Cold (-20°F)	3.4-38
Figure 3.5-1	HAC Fire Transient, FuelSolutions™ W74 Canister, Hot Initial Conditions	3.5-8
Figure 3.5-2	HAC Fire Transient, FuelSolutions™ W74 Canister, Cold Initial Conditions	3.5-9
Figure 3.6-1	Gas Node and Flow Pattern in a Horizontal Canister	3.6-23
Figure 3.6-2	Circulation Pattern within NUHOMS® 24 Unit DSC	3.6-24
Figure 3.6-3	Temperature Distribution in NUHOMS® 24 Unit Basket	3.6-25
Figure 3.6-4	Double Open-Ended Cavity with Two Heated Walls	3.6-25
Figure 3.6-5	Gas Mixture Thermal Conductivity vs. Fission Gas Mole Fraction	3.6-26
Figure 3.6-6	Change in Buoyancy Forces Due to Addition of Fission Gases To Helium Backfill Gases	3.6-26
Figure 3.6-7	Combined Effect on Convection Heat Transfer Due to Addition of Fission Gases	3.6-27
Figure 3.6-8	Effect of Reconfigured, Damaged Fuel on W74 Canister Temperatures Within W150 Transfer Cask	3.6-28
Figure 4.1-1	W74 Damaged Fuel Can	4.1-3
Figure 5.3-1	Normal Condition Detector Locations	5.3-16
Figure 5.3-2	Accident Condition Detector Locations	5.3-17
Figure 5.3-3	W74 Side R-Z Gamma Model (normal conditions)	5.3-18
Figure 5.3-4	W74 Neutron R-Z Model (normal conditions)	5.3-19
Figure 5.3-5	W74 Gamma and Neutron R-Z Model (accident conditions)	5.3-20
Figure 5.3-6	W74 Bottom End Gamma Model (normal and accident conditions)	5.3-21
Figure 5.3-7	W74 Top End Gamma Model (normal and accident conditions)	5.3-22
Figure 6.3-1	FuelSolutions™ W74 Basket (Nominal Dimensions)	6.3-22
Figure 6.3-2	FuelSolutions™ W74 Type A Guide Tube Assembly (Nominal Dimensions)	6.3-23
Figure 6.3-3	FuelSolutions™ W74 Type B Guide Tube Assembly (Nominal Dimensions)	6.3-24
Figure 6.3-4	FuelSolutions™ W74 Shell Assembly and Representative Transportation Cask	6.3-25
Figure 6.3-5	FuelSolutions™ W74 Shell Assembly and TS125 Transportation Cask	6.3-26

LIST OF FIGURES (continued)

Figure	Title	Page
Figure 6.3-6	Horizontal Cross-Section of MCNP Model	6.3-27
Figure 6.3-7	Side View of Lower Portion of FuelSolutions™ W74 HAC Model (cut-away)	6.3-28
Figure 6.3-8	Side View of Middle Portion of the FuelSolutions™ W74 HAC Model (cut-away)	6.3-29
Figure 6.3-9	Side View of Upper Portion of the FuelSolutions™ W74 HAC Model (cut-away)	6.3-30
Figure 6.3-10	FuelSolutions™ W74 Fuel Pattern No. 1 Basket Configuration	6.3-31
Figure 6.3-11	FuelSolutions™ W74 Pattern No. 2 Basket Configuration	6.3-32
Figure 6.3-12	FuelSolutions™ W74 Pattern No. 3 Basket Configuration	6.3-33
Figure 6.3-13	W74 Canister Post-Drop Guide Tube Deformation	6.3-34
Figure 6.3-14	Side View of Lower Portion of FuelSolutions™ W74 NCT Model (cut-away)	6.3-35
Figure 6.3-15	Side View of Middle Portion of FuelSolutions™ W74 NCT Model (cut-away)	6.3-36
Figure 6.3-16	Side View of Upper Portion of the FuelSolutions™ W74 NCT Model (cut-away)	6.3-37
Figure 6.3-17	FuelSolutions™ W74 Basket Model for MOX and Damaged Assembly Analyses (Nominal Dimensions)	6.3-38
Figure 6.3-18	W74 Damaged Fuel Can Configuration	6.3-39
Figure 6.4-1	Multiple Pin Enrichment Pattern 1 for the Big Rock Point GE 9x9 Fuel	6.4-18
Figure 6.4-2	Multiple Pin Enrichment Pattern 2 for the Big Rock Point GE 9x9 Fuel Assembly.	6.4-19
Figure 6.4-3	Multiple Pin Enrichment Pattern 3 for the Big Rock Point GE 9x9 Fuel Assembly	6.4-20
Figure 6.4-4	Multiple Pin Enrichment Pattern 4 for the Big Rock Point Siemens 9x9 Fuel Assembly	6.4-21
Figure 6.4-5	Multiple Pin Enrichment Pattern 1 for the Big Rock Point Siemens 11x11 Fuel Assembly	6.4-22
Figure 6.4-6	Multiple Pin Enrichment Pattern 2 for the Big Rock Point Siemens 11x11 Fuel Assembly	6.4-23
Figure 6.4-7	Multiple Pin Enrichment Pattern 3 for the Big Rock Point Siemens 11x11 Fuel Assembly	6.4-24
Figure 6.4-8	Multiple Pin Enrichment Pattern 4 for the Big Rock Point Siemens 11x11 Fuel Assembly	6.4-25
Figure 6.6-1	J2 (9x9) BRP MOX Assembly Array	6.6-49
Figure 6.6-2	DA (11x11) BRP MOX Assembly Array	6.6-50
Figure 6.6-3	G-Pu (11x11) BRP MOX Assembly Array	6.6-51
Figure 6.6-4	UO_2 9x9 BRP Assembly with Two Inserted MOX Rods	6.6-52
Figure 6.6-5	D72 Partial Assembly Array - J2 Assembly Type	6.6-53
Figure 6.6-6	D73 Partial Assembly Array - J2 Assembly Type	6.6-54
Figure 6.6-7	G01 Partial Assembly Array - G-Pu Assembly Type	6.6-55
Figure 6.6-8	G02 Partial Assembly Array - G-Pu Assembly Type	6.6-56
Figure 6.6-9	K_{eff} vs. H-to-^{235}U Ratio for GE 9x9 BRP Fuel Rod Arrays (Single Assembly Sized Fuel Rod Array with Full Water Reflection)	6.6-57
Figure 6.6-10	K_{eff} vs. H-to-^{235}U Ratio for Siemens 11x11 BRP Fuel Rod Arrays (Single Assembly Sized Fuel Rod Array with Full Water Reflection)	6.6-58

LIST OF FIGURES (continued)

Figure **Title** **Page**

Figure 6.6-11 - K_{eff} vs. H / ^{235}U Ratio for a Square Array of 0.471-inch Diameter Fuel Cylinders 6.6-59
Figure 6.6-12 - K_{eff} vs. H / ^{235}U Ratio for a Square Array of 0.3715-inch Diameter Fuel Cylinders 6.6-60
Figure 6.6-13 - K_{eff} vs. H / ^{235}U Ratio for a Hexagonal Array of 0.471-inch Diameter Fuel Cylinders 6.6-61
Figure 6.6-14 - K_{eff} vs. H / ^{235}U Ratio for a Hexagonal Array of 0.3715-inch Diameter Fuel Cylinders 6.6-62
Figure 6.6-15 - K_{eff} vs. H / ^{235}U Ratio for a Hexagonal Array of 0.9 cm Diameter Fuel Spheres 6.6-63
Figure 6.6-16 - W74 Canister k_{eff} vs. Damaged Fuel Can Interior and Canister Interior Moderator Densities 6.6-64

This page intentionally left blank.

Additional product literature that describes the properties of the EN plating used for this application is provided in Section 1.3.2.2.

The FuelSolutions™ W74M basket spacer plates are fabricated from EN-plated, high-strength carbon steel and high-strength stainless steel. The FuelSolutions™ W74T basket spacer plates are fabricated from EN-plated high-strength carbon steel, except for the bottom spacer plate. The bottom spacer plate is fabricated form high-strength stainless steel to facilitate a welded attachment of the guide tube retainer clip. The support tubes for both the FuelSolutions™ W74T and the W74M basket are constructed of high-strength stainless steel. All basket support sleeves are constructed of stainless steel. The basket openings are fitted with guide tube assemblies that consist of built-up layers of an inner structural tube and borated neutron absorber sheets. The inner structural tube is constructed of austenitic stainless steel for both the FuelSolutions™ W74T and W74M class basket assemblies. The borated stainless steel neutron absorbers are attached to the inner tubes with welded stainless steel retainers. The specific material designations for the FuelSolutions™ W74T class basket assemblies are shown on the drawings in Section 1.3.1.

The FuelSolutions™ W74 canister top end closure consists of a thick shield plug assembly, an inner closure plate with an instrument port cover, a vent port cover, a drain port cover, and an outer closure plate with leak test port cover. The shield plug assembly provides biological shielding for loading of the SNF assemblies in the upper basket and for canister closure operations. The inner and outer closure plates and port covers provide redundant welded closures to assure that the canister maintains confinement function during dry storage. All canister top end closure welds are liquid dye penetrant, including the inner closure welds at the root and final weld passes, and the outer closure weld at the root, intermediate, and final weld passes. In addition, the top end inner closure welds (with the exception of the vent, drain, and leak test port covers) are helium pressure tested and leak tested. This assures that the inert helium atmosphere, the integrity of the canister basket assemblies, and the contained SNF assemblies are maintained during storage and transport. Additional discussion of the FuelSolutions™ canister closure is provided in Section 2.5.2 of the FuelSolutions™ W74 Canister Storage FSAR.

The bottom end closure welding, examination, pressure testing, and leak testing is performed during canister fabrication. All longitudinal and circumferential seam welds in the canister shell are 100% radiographically examined, full penetration butt welds. The canister bottom end plate includes a weld neck to facilitate a full penetration weld to the canister shell. The canister bottom end plate weld to the canister shell is 100% radiographically examined. In addition, the bottom end plate weld and canister shell seam welds are helium pressure tested and leak tested. The canister shell extension and bottom end plate attachment welds are non-pressure retaining welds and are liquid dye penetrant examined.

Gross Weight and Dimensions

The maximum gross shipping weight of a FuelSolutions™ Transportation Package, including the FuelSolutions™ TS125 Transportation Cask with impact limiters, the canister, and the SNF payload, is nominally 285,000 lbs. The package weight is addressed further in Section 1.2.1.5 of the FuelSolutions™ TS125 Transportation Cask SAR.

The breakdown of weights for both FuelSolutions™ W74 canister classes with the associated SNF assembly classes and configurations are provided in Section 2.2 of this SAR. The maximum loaded dry weight of a sealed FuelSolutions™ W74 canister is approximately 77,500 lbs. This is within the design criteria used for the transportation cask discussed in Section 1.2.3 of the FuelSolutions™ TS125 Transportation Cask SAR.

The overall dimensions of each type of FuelSolutions™ W74 canister are summarized in Table 1.2-2 and shown on the drawings contained in Section 1.3.1. These canister dimensions conform to the standardized physical interface with the FuelSolutions™ TS125 Transportation Cask, as discussed in the FuelSolutions™ TS125 Transportation Cask SAR.

1.2.1.2 Other FuelSolutions™ Canister Features

Receptacles, Valves, Testing/Sampling Ports

The ports on a FuelSolutions™ W74 canister include a drain port, a vent port, and an instrument port. The drain and vent ports are used to drain the canister cavity and to backfill it with helium following canister fuel loading, to provide an inert atmosphere for dry storage and transport. The instrument port is for pressure monitoring during FuelSolutions™ W74 canister reflooding, if unloading is necessary. Additional discussion of the canister design features used for canister fuel loading and unloading are provided in Section 1.2.1.3 of the FuelSolutions™ W74 Canister Storage FSAR.

The FuelSolutions™ W74 canister ports are not part of the FuelSolutions™ Transportation Package containment boundary. The location of receptacles, valves, and ports on the containment boundary of the FuelSolutions™ TS125 Transportation Cask is addressed in Section 1.2.1.6 of the FuelSolutions™ TS125 Transportation Cask SAR.

Heat Dissipation

The design basis heat load of the radioactive contents for a FuelSolutions™ W74 canister for transportation is 22,000 watts, with a maximum linear heat generation rate (LHGR) of 192 watts/inch. The design basis axial heat generation profile for the FuelSolutions™ W74 canister is discussed in Section 3.1.3 of this SAR. Heat dissipation from a FuelSolutions™ TS125 Transportation Cask is addressed in Section 1.2.3.4 of the FuelSolutions™ TS125 Transportation Cask SAR.

Coolants

No coolants are used within a FuelSolutions™ W74 canister other than helium within the canister cavity, as discussed in Chapter 3 of this SAR. Coolants for the FuelSolutions™ TS125 Transportation Cask are addressed in Section 1.2.1.6 of the FuelSolutions™ TS125 Transportation Cask SAR.

Protrusions

There are no protrusions on a FuelSolutions™ W74 canister. Protrusions on the FuelSolutions™ TS125 Transportation Cask are addressed in Section 1.2.1.6 of the FuelSolutions™ TS125 Transportation Cask SAR.

Lifting and Tiedown Devices

The device for lifting a FuelSolutions™ W74 canister to facilitate canister transfer is the top end outer closure plate, which has threaded counterbores for attaching a vertical lift fixture. Additional discussion of the canister design features used for canister transfer are provided in Section 1.2.1.3 of the FuelSolutions™ W21 Canister Storage FSAR.

Since the FuelSolutions™ W21 canister is transported inside of a FuelSolutions™ TS125 Transportation Cask, the requirements for lifting and tiedown devices are not applicable to a FuelSolutions™ W74 canister. The design of the FuelSolutions™ TS125 Transportation Cask for lifting and tie down is addressed in Section 1.2.1.6 of the FuelSolutions™ TS125 Transportation Cask SAR.

Pressure Relief System

The FuelSolutions™ W74 canister is a seal welded pressure vessel with no penetrations that is designed to withstand the maximum internal pressure for all design basis conditions. Thus, there is no pressure relief system on a FuelSolutions™ W74 canister. Pressure relief for the FuelSolutions™ TS125 Transportation Cask is addressed in Section 1.2.1.6 of the FuelSolutions™ TS125 Transportation Cask SAR.

Shielding

A FuelSolutions™ W74 canister loaded with SNF assemblies contains both gamma and neutron radiation sources. Biological shielding for the package is provided as follows:

- For the attenuation of gamma radiation, shielding between the radioactive contents and the exterior surface of a package is provided by the FuelSolutions™ TS125 Transportation Cask and also by the FuelSolutions™ W74 canister (the internal basket assembly, cylindrical shell, shield plugs at each end, redundant top closure plates, the bottom closure plate, and the bottom end plate).
- For attenuation of neutron radiation, the center region of the transportation cask body between the impact limiters and the bottom end of the cask have a layer of hydrogenous, solid neutron shielding material.

Further discussion of the shielding characteristics of the FuelSolutions™ W74 canister is provided in Chapter 5 of this SAR. The shielding features for the FuelSolutions™ TS125 Transportation Cask are described in Section 1.2.1.6 of the FuelSolutions™ TS125 Transportation Cask SAR.

Miscellaneous Features

An SNF fuel assembly that is considered to be a damaged fuel assembly, as defined in Section 1.2.3, is placed in a Fuel Solutions™ W74 damaged fuel can to assure that the associated fissile and radioactive materials remain within the damaged fuel can. The damaged fuel can is designed and fabricated using the same material to the same criteria as the canister basket guide tubes. The damaged fuel can is sized to accommodate an SNF assembly and incorporates borated stainless steel neutron absorbers for criticality control. The damaged fuel can has a bottom plate and lid with screened holes to provide for water drainage and vacuum drying following canister fuel loading. The damaged fuel can lid is removable and has mechanical catches that secure it to

the can assembly. The lid has lifting handles to allow the lid and the damaged fuel can to be handled and placed in the Fuel Solutions™ W74 canister basket. The damaged fuel cans are placed in the support tubes of the upper and lower basket assemblies, which are oversized for this purpose. Drawings for the Fuel Solutions™ W74 damaged fuel can are provided in Section 1.3.1.

Permanent FuelSolutions™ W74 canister identification information is provided on the outside of the top closure plate and the bottom end plate. The permanent identification markings on the FuelSolutions™ W74 canister are discussed further in Section 9.1.7.2 of the FuelSolutions™ W74 Canister Storage FSAR.

1.2.1.3 Non-Packaging Support Equipment

The FuelSolutions™ support equipment used to facilitate FuelSolutions™ W74 canister loading, closure, and transfer operations is shown schematically in Figure 1.2-1 and described in Section 1.2.1.4 of the FuelSolutions™ Storage System FSAR. In addition, FuelSolutions™ support equipment is used to handle and transport the FuelSolutions™ Transportation Package, as described in Section 1.2.1.7 of the FuelSolutions™ TS125 Transportation Cask SAR.

1.2.2 Operational Features

The operations associated with the FuelSolutions™ TS125 Transportation Cask and the FuelSolutions™ W74 canisters are similar to other licensed transportation packages. The FuelSolutions™ W74 canisters are designed to be loaded in a spent fuel pool while inside a FuelSolutions™ TS125 Transportation Cask. However, a FuelSolutions™ W74 canister being loaded for on-site storage prior to off-site transport would typically be loaded while inside a FuelSolutions™ W100 Transfer Cask, as described in Section 1.2.2 of the FuelSolutions™ W74 Canister Storage FSAR. After interim storage on-site, a loaded FuelSolutions™ W74 canister can be transferred from a FuelSolutions™ W150 Storage Cask into a FuelSolutions™ TS125 Transportation Cask using a FuelSolutions™ W100 Transfer Cask. With a transfer cask, a loaded FuelSolutions™ W74 canister can be transferred into a FuelSolutions™ TS125 Transportation Cask either vertically or horizontally using FuelSolutions™ SFMS support equipment. These capabilities and equipment are discussed further in Section 1.2.2 of the FuelSolutions™ TS125 Transportation Cask SAR.

FuelSolutions™ W74 Canister

The FuelSolutions™ W74 canister incorporates several design features to facilitate off-site canister transportation operations. These features include the following:

- Top and bottom shield plugs, which allow vertical or horizontal canister transfer while maintaining occupational exposures ALARA.
- Threaded counterbores on the outer top closure plate for vertical lifting fixture attachment and installation of the horizontal transfer pintle.
- Threaded counterbores on the bottom end plate for installation of the horizontal transfer pintle.

Table 1.2-4 - FuelSolutions™ W74 Canister SNF Assembly Acceptance Criteria for Transport (6 pages)

Payload Designation	W74-1: Intact UO_2 Fuel Assemblies
SNF Parameter	**Loading/Acceptance Criteria**
Payload Description	≤ 64 Big Rock Point BWR intact[1, 2] UO_2 fuel assemblies, as defined in Table 1.2-5. Any remaining empty canister basket guide tubes and/or support tubes may be loaded with fuel assemblies meeting any of the acceptable payload specifications W74-2 through W74-6, subject to the limitations of those specifications. If less than 64 total fuel assemblies are loaded, a dummy fuel assembly is to be placed into each empty canister basket guide tube and/or support tube. Each dummy fuel assembly is to be the approximate weight and size of the intact fuel assembly, as defined in Table 1.2-5.
Cladding Material/Condition	Zircaloy cladding with no known or suspected cladding defects greater than hairline cracks or pinhole leaks.
Maximum Weight	≤ 485 pounds per fuel assembly, as defined in Table 1.2-5.
Maximum Heat Load	≤ 0.344 kW per fuel assembly.
Maximum Uranium Loading	≤ 142.1 kg, as defined in Table 1.2-6.
Maximum Initial Enrichment[3]	≤ 4.10 w/o ^{235}U, as defined in Table 1.2-6 for the fuel assembly parameters defined in Table 6.1-1 of this SAR.
Maximum Burnup	≤ 32,000 MWd/MTU, as defined in Table 1.2-6.
Minimum Cooling Time	≥ 6.0 years, irrespective of fuel assembly type, enrichment, burnup; and total cobalt content, as defined in Table 1.2-6. The effects of the maximum acceptable gamma and neutron sources are incorporated into the minimum cooling time determination.[4]

W74-1 Notes:

(1) Intact fuel assemblies include those BRP fuel assemblies with 1 to 4 corner rods missing, and BRP 9x9 fuel assemblies with 1 rod missing from a non-corner location. This includes assemblies with partial length rods, or rod fragments inside stainless tubes, in any of the array corner locations. It also includes 9x9 assemblies with 11x11 assembly rods in corner locations.

(2) Intact assemblies may have any number of fuel rods replaced with solid zircaloy or stainless steel rods, or with poison rods. They may also have any object other than fuel rods placed in the empty array or guide tube locations, including all forms of inserts or control components.

(3) Defined as the maximum array-average enrichment, which is the peak planar average initial enrichment considering all elevations along the assembly axis.

(4) If an SNF assembly has been further irradiated after having fuel rods replaced by dummy stainless rods, an evaluation must be performed that shows that the active fuel region non-fuel gamma source strength is bounded by that described in Section 5.2.2.1 of this SAR.

Table 1.2-4 - FuelSolutions™ W74 Canister SNF Assembly Acceptance Criteria for Transport (6 pages)

Payload Designation	W74-2: Intact MOX Fuel Assemblies
SNF Parameter	**Loading/Acceptance Criteria**
Payload Description	≤ 64 Big Rock Point BWR intact MOX fuel assemblies, as defined in Table 1.2-6. Any remaining empty canister basket guide tubes and/or support tubes may be loaded with fuel assemblies meeting any of the acceptable payload specifications W74-1 and W74-3 through W74-6, subject to the limitations of those specifications. If less than 64 total fuel assemblies are loaded, a dummy fuel assembly must be placed into each empty canister basket guide tube and/or support tube. Each dummy fuel assembly must be the approximate weight and size of the intact fuel assembly, as defined in Table 1.2-5.
Cladding Material/Condition	Zircaloy cladding with no known or suspected cladding defects greater than hairline cracks or pinhole leaks.
Maximum Weight	≤ 485 pounds per fuel assembly, as defined in Table 1.2-5.
Maximum Heat Load	≤ 0.344 kW per fuel assembly.
Maximum Heavy Metal Loading	The heavy metal loading varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7.
Maximum Initial Enrichment	The fuel rod initial enrichment varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7 for MOX fuel assembly arrays bounded by those shown in Figures 6.6-1 through 6.6-4 of this SAR.
Maximum Burnup	The burnup varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7.
Minimum Cooling Time	The cooling time varies by fuel assembly type and must not be less than the minimum values defined in Table 1.2-7. The effects of the maximum acceptable gamma and neutron sources are incorporated into the minimum cooling time determination.

W74-2 Note:

Notes 1, 2, and 4 for W74-1 apply to W74-2.

Table 1.2-4 - FuelSolutions™ W74 Canister SNF Assembly Acceptance Criteria for Transport (6 pages)

Payload Designation	W74-3: Partial UO_2 Fuel Assemblies
SNF Parameter	**Limit/Specification**
Payload Description	≤ 64 Big Rock Point BWR partial UO_2 fuel assemblies, as defined in Table 1.2-6. Partial fuel assemblies are defined as those assemblies having one or more full-length fuel rods missing from the intact fuel assemblies defined in Table 1.2-6 (except as permitted by W74-1 Note 1). The affected array locations may contain nothing, partial length rods, hollow zircaloy or stainless steel rods, neutron source rods, or any other non-fissile material object that displaces less water than a full-length fuel rod. Any remaining empty canister basket guide tubes and/or support tubes may be loaded with fuel assemblies meeting any of the acceptable loading specifications W74-1, W74-2, and W74-4 through W74-6, subject to the limitations of those specifications. If less than 64 total fuel assemblies are loaded, a dummy fuel assembly must be placed into each empty canister basket guide tube and/or support tube. Each dummy fuel assembly must be the approximate weight and size of the intact fuel assembly, as defined in Table 1.2-5.
Cladding Material/Condition	Zircaloy cladding with no known or suspected cladding defects greater than hairline cracks or pinhole leaks.
Maximum Weight	≤ 485 pounds per fuel assembly, as defined in Table 1.2-5.
Maximum Heat Load	≤ 0.344 kW per fuel assembly.
Maximum Uranium Loading	≤ 142.1 kg, as defined in Table 1.2-6.
Maximum Initial Enrichment(1)	≤ 3.55 w/o ^{235}U (missing array interior or edge rods - 9x9) ≤ 3.6 w/o ^{235}U (missing array interior or edge rods - 11x11)
Maximum Burnup	≤ 32,000 MWd/MTU, as defined in Table 1.2-6.
Minimum Cooling Time	≥ 6.0 years, irrespective of fuel assembly type, enrichment, burnup; and total cobalt content, as defined in Table 1.2-6. The effects of the maximum acceptable gamma and neutron sources are incorporated into the minimum cooling time determination.

W74-3 Notes:

(1) Defined as the maximum array average initial enrichment, which is the peak planar average initial enrichment considering all elevations along the fuel assembly axis. The averaging is applied only to those fuel rods that are present in the partial array.

(2) Notes 2 and 4 for W74-1 apply to W74-3.

Table 1.2-4 - FuelSolutions™ W74 Canister SNF Assembly Acceptance Criteria for Transport (6 pages)

Payload Designation	W74-4: Partial MOX Fuel Assemblies
SNF Parameter	**Loading/Acceptance Criteria**
Payload Description	≤ 64 Big Rock Point BWR partial MOX fuel assemblies, as defined in Table 1.2-7. Partial fuel assemblies are defined as those assemblies having one or more full-length fuel rods missing from the intact fuel assemblies defined in Table 1.2-7 (except as permitted by W74-1 Note 1). The affected array locations may contain nothing, partial length rods, hollow zircaloy or stainless steel rods, neutron source rods, or any other non-fissile material object that displaces less water than a full-length fuel rod. Any remaining empty canister basket guide tubes and/or support tubes may be loaded with fuel assemblies meeting any of the acceptable loading specifications W74-1 through W74-3, W74-5, and W74-6, subject to the limitations of those specifications. If less than 64 fuel assemblies are loaded, a dummy fuel assembly must be placed into each empty canister basket guide tube and/or support tube. Each dummy fuel assembly must be the approximate weight and size of the intact fuel assembly, as defined in Table 1.2-5.
Cladding Material/Condition	Zircaloy cladding with no known or suspected cladding defects greater than hairline cracks or pinhole leaks.
Maximum Weight	≤ 485 pounds per fuel assembly, as defined in Table 1.2-5.
Maximum Heat Load	≤ 0.344 kW per fuel assembly.
Maximum Heavy Metal Loading	The heavy metal loading varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7.
Maximum Initial Enrichment	The fuel rod initial enrichment varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7 for the partial MOX fuel assembly arrays bounded by those shown in Figures 6.6-5 through 6.6-8 of this SAR.
Maximum Burnup	The burnup varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7.
Minimum Cooling Time	The cooling time varies by fuel assembly type and must not be less than the minimum values defined in Table 1.2-7. The effects of the maximum acceptable gamma and neutron sources are incorporated into the minimum cooling time determination.

W74-4 Note:

Note 4 for W74-1 applies to W74-4.

Table 1.2-4 - FuelSolutions™ W74 Canister SNF Assembly Acceptance Criteria for Transport (6 pages)

Payload Designation	W74-5: Damaged UO_2 Fuel Assemblies
SNF Parameter	**Limit/Specification**
Payload Description	≤ 8 Big Rock Point BWR damaged UO_2 fuel assemblies. Damaged fuel assemblies are defined as those with fuel rod damage in excess of hairline cracks or pinhole leaks. Fuel assemblies with damaged grid spacers (defined as damaged to a degree where fuel rod structural integrity cannot be assured, or where grid spacers have shifted vertically from their design position) are also considered to be damaged fuel assemblies. Each fuel assembly designated as damaged must be placed within a damaged fuel can and loaded into one of the four basket support tube locations in the upper and lower basket of the canister. The remaining empty canister basket guide tubes and support tubes may be loaded with fuel assemblies meeting any of the acceptable loading specifications W74-1 through W74-4 and W74-6, subject to the limitations of those specifications, for a total of ≤ 64 Big Rock Point BWR fuel assemblies. If less than 64 fuel assemblies are loaded, a dummy fuel assembly must be placed into each empty canister basket guide tube and/or support tube. Each dummy fuel assembly must be the approximate weight and size of the intact fuel assembly, as defined in Table 1.2-5.
Cladding Material/Condition	Zircaloy cladding with fuel rod damage in excess of hairline cracks or pinhole leaks.
Maximum Weight	≤ 685 pounds per canned fuel assembly.
Maximum Heat Load	≤ 0.344 kW per fuel assembly.
Maximum Uranium Loading	≤ 142.1 kg, as defined in Table 1.2-6.
Maximum Initial Enrichment	≤ 4.61 w/o ^{235}U peak fuel pellet initial enrichment.
Maximum Burnup	≤ 32,000 MWd/MTU, as defined in Table 1.2-6.
Minimum Cooling Time	≥ 6.0 years, irrespective of fuel assembly type, enrichment, burnup; and total cobalt content, as defined in Table 1.2-6. The effects of the maximum acceptable gamma and neutron sources are incorporated into the minimum cooling time determination.

W74-5 Note:

Note 4 for W74-1 applies to W74-5.

Table 1.2-4 - FuelSolutions™ W74 Canister SNF Assembly Acceptance Criteria for Transport (6 pages)

Payload Designation	W74-6: Damaged MOX Fuel Assemblies
SNF Parameter	**Limit/Specification**
Payload Description	≤ 8 Big Rock Point BWR damaged MOX fuel assemblies. Damaged fuel assemblies are defined as those with fuel rod damage in excess of hairline cracks or pinhole leaks. Fuel assemblies with damaged grid spacers (defined as damaged to a degree where the fuel rod structural integrity cannot be assured, or where the grid spacers have shifted vertically from their design position) are also considered to be damaged fuel assemblies. Each fuel assembly designated as damaged must be placed within a damaged fuel can and loaded into one of the four basket support tube locations in the upper and lower basket of the canister. The remaining empty canister basket guide tubes and support tubes may be loaded with fuel assemblies meeting any of the acceptable loading specifications W74-1 through W74-5, subject to the limitations of those specifications, for a total of ≤ 64 Big Rock Point BWR fuel assemblies. If less than 64 fuel assemblies are loaded, a dummy fuel assembly must be placed into each empty canister basket guide tube and/or support tube. Each dummy fuel assembly must be the approximate weight and size of the intact fuel assembly, as defined in Table 1.2-5.
Cladding Material/ Condition	Zircaloy cladding with fuel rod damage in excess of hairline cracks or pinhole leaks.
Maximum Weight	≤ 685 pounds per canned fuel assembly.
Maximum Heat Load	≤ 0.344 kW per fuel assembly.
Maximum Heavy Metal Loading	The heavy metal loading varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7.
Maximum Initial Enrichment	≤ 4.61 w/o ^{235}U peak fuel pellet initial enrichment for all MOX fuel assembly types defined in Table 1.2-7, based on the formula $E_{U\text{-}235} + 0.7 \times P_{PU}$, where $E_{U\text{-}235}$ is the ^{235}U initial enrichment of the uranium in the fuel pellet, and P_{PU} is the overall w/o of plutonium in the fuel pellet.
Maximum Burnup	The burnup varies by fuel assembly type and must not exceed the maximum values defined in Table 1.2-7.
Minimum Cooling Time	The cooling time varies by fuel assembly type and must not be less than the minimum values defined in Table 1.2-7. The effects of the maximum acceptable gamma and neutron sources are incorporated into the minimum cooling time determination.

W74-6 Note:

Note 4 for W74-1 applies to W74-6.

- *NCT Cold (no heat):* This case is the same as NCT Cold, but without decay heat. This analytically trivial case addresses minimum material temperatures for the brittle fracture evaluation presented in Section 2.6.2 of this SAR.
- *NCT Cold Environment:* A -40°F steady-state ambient temperature with maximum decay heat and zero insolation. This case is used for evaluation of the maximum thermal gradients and is not combined with other structural loads.
- *NCT Cold Environment (no heat):* This case is the same as NCT Cold Environment, but without decay heat. Similar to NCT Cold (no heat), this analytically trivial case establishes minimum material temperatures for material compatibility and for the brittle fracture evaluation presented in Section 2.6.2.
- *HAC Fire (cold):* Thermal conditions are evaluated as a steady-state ambient temperature of -20°F with maximum decay heat and zero insolation prior to the event, followed by a thirty-minute transient with an ambient temperature of 1475°F with maximum decay heat, and then back to a steady-state ambient temperature of -20°F with maximum decay heat and zero insolation. This case is used for evaluation of the thermal gradients expected under the HAC fire conditions. Comparison with the results from the HAC Fire (hot) case below provides an indication of the sensitivity of the package thermal response to the HAC event with the initial starting temperature.
- *HAC Fire (hot):* Thermal conditions are evaluated as a steady-state ambient temperature of 100°F with maximum decay heat and zero insolation prior to the event, followed by a thirty-minute transient with an ambient temperature of 1475°F with maximum decay heat and maximum insolation, and then back to a steady-state ambient temperature of 100°F with maximum decay heat and maximum insolation, per 10CFR71.71(c)(1), averaged over 24 hours. This load case evaluates the peak temperature achieved for the various cask components under the HAC fire event and the associated thermal stresses.

The 10CFR71.71(c)(1) insolation values are applied to the transportation cask as discussed in Section 3.1.2 of the FuelSolutions™ TS125 Transportation Cask SAR,[2] and their effects are included in the W74 canister thermal evaluations provided herein. The insolation values are applied to the transportation package as a 24-hour average. Transient insolation modeling is not considered[7,8] due to the large thermal inertia of the transportation package and the relative magnitude of the insolation load compared to the heat load provided by the SNF.

3.1.3 Design Basis Axial Heat Generation Profile

The FuelSolutions™ W74 canister is designed to accommodate only Big Rock Point BWR fuel. In order to assure that the W74 canister design configurations presented in Section 1.2 of this SAR are qualified to accommodate the worst-case thermal loads, a conservative design basis axial

[7] Brown, N., Gianoulakis, S., and Lake, W., *Comparison of 10 CFR 71 Normal Conditions with Bounding US "Hot Day" Extremes,* Sandia Report SAND91-2255C, October 1992.

[8] Manson, S., and Gianoulakis, S., *Comparison of Spent Fuel Shipping Cask Response to 10 CFR 71 Normal Conditions and Realistic Hot Day Extremes,* Sandia Report SAND94-0812, April 1994.

heat generation profile is used in the thermal analysis. The axial heat generation profile and, hence, the temperature profile within the FuelSolutions™ W74 canister are dependent on the variation in the heat load and axial location of the fuel assembly loaded within each basket. The distribution of the heat load within the canister is a function of: (1) the SNF assembly class (i.e., Big Rock Point BWR), (2) the corresponding heavy metal content, burnup, and cooling time, (3) the number of SNF assemblies in the canister, (4) the active length of the SNF assemblies, and (5) the axial position of the SNF assembly active fuel length within the canister. The above variables are set by the canister type and the characteristics of the specific Big Rock Point fuel to be loaded. Sections 3.1.3.1 and 3.1.3.2 describe how the design basis heat generation profile is determined and applied.

In order to address the axial heat profile variations with fuel assembly class and burnup, two thermal acceptance criteria are used for the W74 canister thermal rating qualification. These thermal acceptance criteria are: (1) the maximum heat load rating (Q), and (2) the maximum linear heat generation rate (LHGR) on a per unit length basis. Both thermal criteria are needed to define the allowable W74 canister thermal loading. Although the total heat load is the major determining factor in the overall temperature levels within the W74 canister, the temperature levels at any specific location are more directly affected by the LHGR. This is especially true where the cask and/or canister design and the material thermal conductivity combine to limit the axial spreading of localized heat effects.

3.1.3.1 Development of the Design Basis Axial Heat Generation Profile

Development of PWR and BWR axial heat generation profiles is addressed in detail in Section 3.1.3 of the FuelSolutions™ TS125 Transportation Cask SAR.[2] The variation in LHGR within the W74 canister is a function of the axial location of the active fuel within the canister. To create a design basis canister axial heat generation profile for use in analyzing the W74 canister, the design basis peaking factor curve for the generic BWR fuel type (Figure 3.1-1 of the FuelSolutions™ TS125 Transportation Cask SAR) is adjusted for the location and length of the active fuel region of the Big Rock Point fuel assemblies within the upper and lower baskets in the W74 canister. Using this profile, a W74 canister-specific axial heat profile is developed. This design basis W74 canister profile, termed the "Big Rock Point" profile (see Figure 3.1-1), envelops the worst-case axial heat profile expected from the fuel to be stored within the W74 canister.

The "Big Rock Point" profile assumes a burnup of 29 GWd/MTU. Burnup for a given fuel assembly class determines the SNF assembly's total heat load (kW) at the time of reactor discharge and the profile of the heat load versus fuel axial position. A uniform burnup over the entire active fuel length would result in a flat axial heat profile with no peaks (i.e., a peaking factor of 1.0). Since fuel does not burn uniformly over the entire axial length, the heat generation from the fuel will exhibit a peak in the center region of the assembly. A curve fit through the maximum peaking factor observed as a function of burnup is presented in Figure 3.1-2 for generic BWR fuel. Because of the variation in peaking factor versus burnup level, an adjustment/penalty factor is included for low burnup fuels to extend the required SNF cooling times even if the total canister maximum heat load rating (Q_{max}) meets the thermal rating criteria established for the transportation cask and the canister type. SNF assemblies with burnups less

than the nominal values are essentially de-rated to normalize the lower burnup peaks with the baseline. Although appropriate, an adjustment/credit is conservatively not applied for SNF assemblies with burnups greater than the nominal values.

The active fuel length of an individual Big Rock Point fuel assembly is 70 inches. Thus, the total active fuel length of the fuel in the upper and lower baskets is 140 inches. However, a 72-inch active fuel length is used for the fuel in the upper basket assembly for the design basis axial heat generation profile shown in Figure 3.1-1. This results in a slight difference between the upper and lower fuel heat generation profiles that does not significantly affect the results of the thermal evaluation. The composite heat loads in the upper and lower baskets each represent approximately one half of the total W74 canister heat load. Since the W74 canister is designed specifically to accommodate only Big Rock Point fuel and since shorter BWR fuels do not exist, there is no need for a shorter "max. thermal gradient" profile, as used in the thermal analysis of other FuelSolutions™ canisters. Therefore, only the "Big Rock Point" profile is needed to bound all possible W74 canister fuel loadings.

Table 3.1-2 presents in tabular form the design basis "Big Rock Point" canister axial heat profile illustrated in Figure 3.1-1. The same axial heat profile is applicable to the MOX, damaged, and partial fuel assemblies.

3.1.3.2 Application of Axial Heat Profiles for Canister Analysis

The FuelSolutions™ W74 canister analytical model used for the thermal evaluation includes simulation of the individual fuel assemblies within the upper and lower baskets. The local decay heat (Q_{local}) at any specific axial location within the fuel assemblies is determined using the Big Rock Point axial profile in Figure 3.1-1 as follows:

$$Q_{Local} = \left(\frac{Q_{Assy}}{AFL}\right) \cdot N(z) \cdot L$$

where:

- Q_{Local} = Local fuel assembly heat load at the nodal location
- Q_{Assy} = Total fuel assembly heat load (kW) for the given axial profile
- AFL = Active fuel length in inches for the associated axial profile (i.e., 70 inches)
- N(z) = Normalized heat generation at the center of the region being modeled (from Figure 3.1-1 or Table 3.1-2)
- L = Axial length in inches of the region being modeled

For determination of the allowable W74 canister thermal rating within the transportation cask, the value of Q_{Assy} is increased until one or more of the canister or cask allowable material temperatures or the allowable fuel cladding temperature are reached. The maximum value of Q_{Assy} that meets all canister/cask allowable temperatures is multiplied by the total number of assemblies (64) to determine the maximum heat load rating (Q_{Total}) for the canister. The corresponding maximum LHGR for each profile is equal to the average heat load (Q_{Total}/(2 x AFL)) multiplied by the peaking factor (PF). In this case, the active fuel length is multiplied by a factor of 2 since there are two baskets inside the W74 canister. In addition, a peaking factor of 1.22 is used for Big Rock Point fuel.

The calculated maximum heat load rating (Q_{Total}) and maximum LHGR become the thermal ratings for the W74 canister. Via this methodology, any combination of fuel cooling time, active length, or burnup that increases the heat load above the qualified Q_{Total} and LHGR values for the canister will restrict the loading of that candidate fuel assembly until sufficient additional cooling time has occurred to reduce the heat load.

3.1.3.3 Compliance with Transportation Cask Thermal Requirements

As discussed in Section 3.1.3.3 of the FuelSolutions™ TS125 Transportation Cask SAR, any FuelSolutions™ canister that is to be transported in the TS125 Transportation Cask must have a design basis canister heat load that does not exceed 22.0 kW, and that does not produce a peak temperature in the inner shell of the TS125 Transportation Cask exceeding that calculated for the transportation cask's Q_{max} thermal profile.

The design basis BRP profile used for the thermal evaluation of the W74 canister has a maximum heat load of 22.0 kW and a maximum LHGR of 0.192 kW/inch. As shown in Table 3.1-3, the BRP profile is compliant with the maximum allowable canister heat load of 22.0 kW for the TS125 transportation cask. However, the maximum LHGR of the BRP profile (0.192 kW/inch) exceeds the maximum LHGR of the Q_{max} profile upon which the TS125 transportation cask thermal rating is based. Comparison of the peak temperature in the TS125 transportation cask from the W74 thermal analysis with those from Chapter 3 of the FuelSolutions™ TS125 Transportation Cask SAR shows that the BRP profile produces lower peak temperatures in the cask inner shell than those calculated for the Q_{max} profile in Chapter 3 of the FuelSolutions™ TS125 Transportation Cask SAR. Therefore, the W74 canister design basis BRP axial heat generation profile satisfies the canister thermal requirements specified in Section 3.1.3.3 of the FuelSolutions™ TS125 Transportation Cask SAR.

3.1.4 Temperature Summary

The maximum allowable material temperatures for the W74 canister components are presented in Section 3.3.1, while the SNF cladding allowable temperature is presented in Section 3.3.2. The canister system temperatures under the various bounding thermal load conditions for transportation are presented in Sections 3.4 and 3.5 for NCT and HAC, respectively. These system temperatures are determined by applying either the maximum W74 canister thermal ratings presented in Table 3.1-3 or zero decay heat, depending on the applicable thermal load condition summarized in Table 3.1-1.

The figures and tables in Section 3.4 provide a comprehensive overview of the thermal performance of the W74 canister in the TS125 cask under NCT conditions. As the thermal analysis of Section 3.4 demonstrates, all of the temperatures and temperature distributions noted from the analysis are well within the established thermal limits for both the canister and the cask. The predicted peak fuel cladding temperature is 656°F (347°C), or 96°F below the conservatively established allowable temperature for the fuel cladding. The peak spacer plate temperature is 615°F, and the peak canister shell temperature is 475°F.

The predicted peak cask shell temperature is 363°F, or 437°F below the established allowable temperature for the structural steel. The maximum predicted temperature of the lead material forming the gamma shield is 354°F, or 266°F below the established melting point for the lead.

The bulk average temperature for the lead shield under the bounding NCT load condition is 334°F. The bulk average temperature of the solid neutron shield material is 261°F, or 39°F below the 300°F limitation established to limit the loss of hydrogen from the material.

Likewise, the thermal evaluations for HAC conditions presented in Section 3.5 demonstrate that the canister and cask component temperatures will remain below their respective accident allowable temperatures. Despite conservative assumptions for emissivity and absorptivity and the worst-case modeling for potential damage to the impact limiters, the thermal evaluations demonstrate that fuel cladding, spacer plates, and other canister components remain within their long-term allowable temperatures, the cask containment boundary remains intact, and that the lead will remain well below its established melting point. The predicted peak fuel cladding temperature is 350°C, or only 7°C above its pre-fire level. Likewise, the peak spacer plate temperature and the peak canister shell temperatures are only 20 and 35°F, respectively, above their pre-fire temperature levels.

The peak cask component temperatures seen for HAC conditions are within their allowable limits. A full discussion of the performance of the TS125 cask under HAC conditions is provided in the FuelSolutions™ TS125 Transportation Cask SAR.[2]

3.1.5 Transportation Cask Internal Pressure Summary

Although designed as a confinement boundary for storage conditions, the FuelSolutions™ W74 canister shell assembly is not considered a containment boundary for transportation conditions. Instead, the transportation cask serves this function. In addition to the cask cavity backfill gas, the transportation cask is conservatively assumed to be pressurized due to a postulated release of fuel rod fill gas, fuel rod fission gas, and canister backfill gas directly to the transportation cask cavity. As discussed in Chapter 7 of this SAR, the W74 canister is backfilled with helium during closure operations. The quantity in moles of inert gas needed for canister cavity backfill is determined in order to achieve 10 psig (1.68 atm) in the canister cavity under normal hot storage conditions (i.e., 100°F ambient at the W74 thermal rating for storage within the FuelSolutions™ W150 Storage Cask) with 1% rod failures. The transportation cask cavity is conservatively assumed to be backfilled with helium to achieve 1 atm at room temperature (70°F). Since it can safely be assumed that the canister/cask temperatures will be above 70°F at the time of backfill, the actual cask cavity pressures will be less than those determined based on this assumed quantity of helium backfill gas.

The transportation cask maximum internal pressure is dependent on the characteristics of the specific FuelSolutions™ W74 canister and its SNF payload. A FuelSolutions™ TS125 Transportation Cask design pressure of 75 psig has been established to bound the maximum pressures resulting from the worst-case combination of canister and SNF. Conservative predictions of transportation cask internal pressure for NCT and HAC are provided in Sections 3.4 and 3.5, respectively. The calculations for NCT assume the rupture of 3% of the SNF and PWR control component rods, while those for HAC assume the rupture 100% of the SNF and PWR

control component rods.[9] The release of 100% of the rod fill gas, 30% of the SNF rod fission gas, and 30% of the gas generated within PWR control components is conservatively assumed for each postulated failed rod.

The maximum normal operating pressure (MNOP) for NCT hot and NCT cold conditions and HAC pressure are presented in Table 3.1-5. As shown, both the MNOP and the HAC pressure generated with a bounding W74 canister remains within the design pressure rating for the FuelSolutions™ TS125 Transportation Cask.

[9] Table 4-1, NUREG-1617, *Standard Review Plan for Transportation Packages for Spent Nuclear Fuel*, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001, March 2000.

Table 3.1-1 - Transportation Design Basis Thermal Conditions

Case	Description	Applicable Conditions				
		Ambient Temperature (°F)	Insolation		Decay Heat	
			Max.[1]	Zero	Max.	Zero
1	NCT Hot[2]	100	x		x	
2	NCT Hot (no solar)[2,3,6]	100		x	x	
3	NCT Cold[2,3]	-20		x	x	
4	NCT Cold (no heat)[4]	-20		x		x
5	NCT Cold Environment[5]	-40		x	x	
6	NCT Cold Environment (no heat)[4]	-40		x		x
7	HAC Fire (cold)[3]	-20/1475/-20		x	x	
8	HAC Fire (hot)[3]	100/1475/100	x		x	

Notes:

(1) Insolation in accordance with 10CFR71.71(c)(1), averaged over 24 hours.

(2) Thermal conditions used to evaluate thermal acceptance criteria and for structural load combinations.

(3) For the HAC fire event, a transient consisting of an initial steady-state initial conditions (i.e. Case 2 or Case 3), followed by a 30-minute fire event, and concluded with a post-fire transient analysis to establish the peak temperatures.

(4) NCT Cold and Cold Environment are evaluated without decay heat to establish minimum material temperatures for material compatibility and brittle fracture considerations.

(5) NCT Cold Environment evaluated with maximum decay heat to establish the worst-case spacer plate thermal gradients.

(6) NCT Hot (no solar) used to assure compliance with 10CFR71.43(g) criteria for accessible surface temperature.

Table 3.1-2 - W74 Canister Design-Basis Axial Heat Profile

Axial Location[1] (Inches)	Big Rock Fuel Profile Peaking Factor[2]
0 – 12.99	0
13	0.21
17.4	0.76
20	0.99
30	1.19
40	1.21
50	1.19
60	1.13
70	0.99
80	0.4889
83 – 97.99	0
98	0.21
102	0.76
110	1.14
120	1.20
130	1.20
140	1.16
150	1.08
160	0.81
164	0.70
168	0.21
170 - 192	0

Notes:

(1) Axial location is given with respect to the bottom end of the canister.

(2) Intermediate values are determined by linear interpolation.

Table 3.1-3 - W74 Canister Maximum Thermal Ratings for Transportation

Component	Maximum Canister Heat Load, Q_{Total} (kW)	Maximum LHGR (kW/in)
W74 Canister BRP Profile	22.0	0.192
TS125 Transportation Cask Q_{max} Profile(1)	22.0	0.1606
W74 Canister Thermal Rating(2)	22.0	0.192

Notes:

(1) The design basis canister heat generation profile that is used for the TS125 transportation cask thermal evaluation in the FuelSolutions™ TS125 Transportation Cask SAR.

(2) As discussed in Section 3.1.3.3, the W74 canister LHGR thermal rating, which exceeds that of the TS125 transportation cask Q_{max} profile, is compliant with the thermal requirements of the TS125 transportation cask since it does not produce higher peak temperatures in the transportation cask inner shell than those in the FuelSolutions™ TS125 Transportation Cask SAR.

Table 3.1-4 - W74 Canister Thermal Ratings vs. SNF Burnup

Burnup (GWd/MTU)	Burnup Value For Group (GWd/MTU)	Peaking Factor, PF	De-rating Factor	Maximum LHGR (kW/in)	Q_{Total} (kW)
0 to 15	7.50	1.459	0.836	0.192	18.3(1)
15 to 20	17.50	1.305	0.935	0.192	20.5(1)
20 to 25	22.50	1.263	0.966	0.192	21.2(1)
25 to 29	27.50	1.231	0.991	0.192	21.8(1)
> 29	-	1.22	1.00	0.192	22.0(2)

Notes:

(1) Thermal rating limited by the W74 canister's maximum LHGR of 0.192 kW/inch. The corresponding maximum canister heat load, Q_{Total}, is limited to (0.192 kW/inch x 140 inches)/PF.

(2) Canister rating limited by maximum thermal rating of 22.0 kW for TS125 Transportation Cask.

Table 3.1-5 - Transportation Cask Internal Pressures with Loaded W74 Canister

Condition	Transportation Cask Pressure	Max. Design Pressure
MNOP[1]	10.7 psig	75 psig
MNOP Cold[2]	8.5 psig	75 psig
Max. HAC Internal Pressure	28.3 psig	75 psig

Notes:

(1) At maximum canister rating and with 100°F ambient and solar.

(2) At maximum canister rating and with -20°F ambient and no solar.

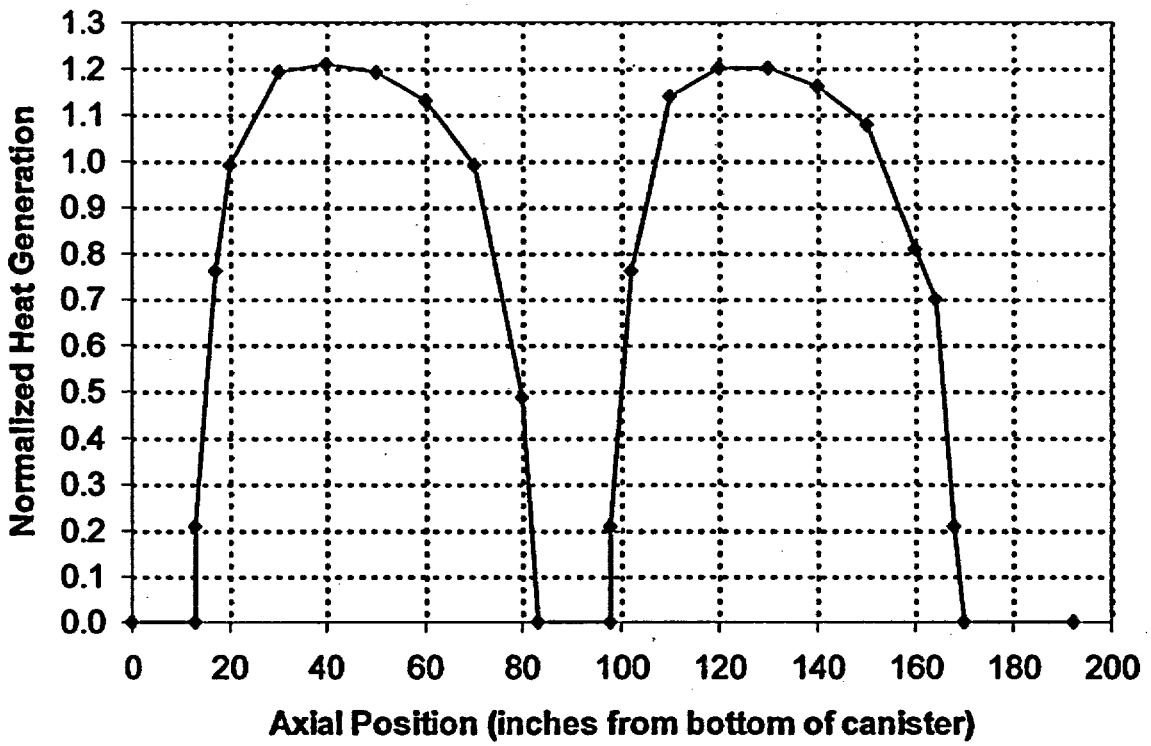

Figure 3.1-1 - Design Basis Axial Heat Profile for W74 Canister Analysis

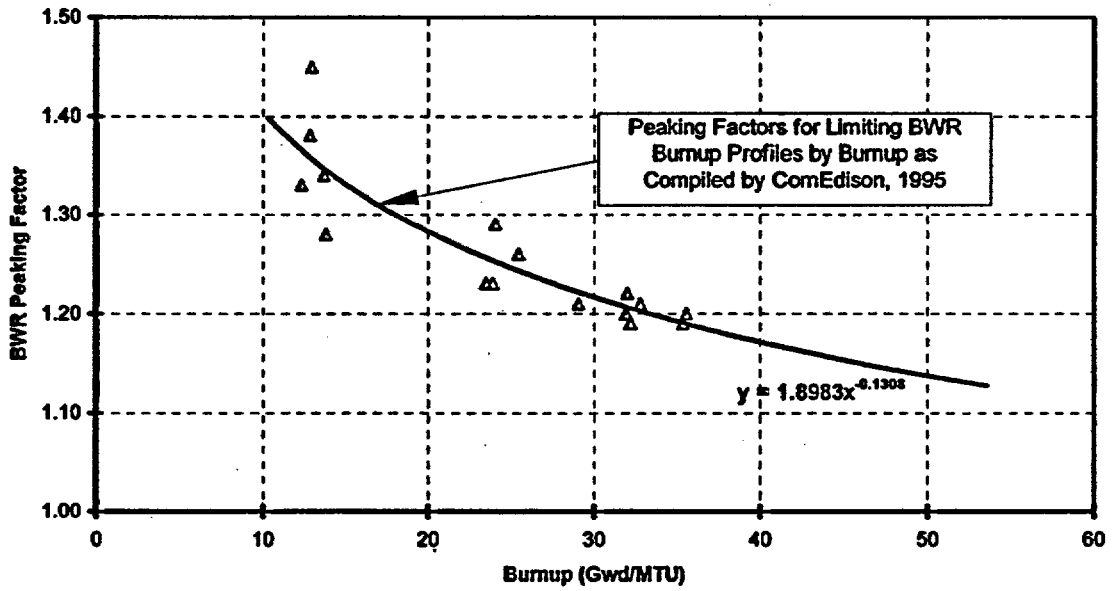

Figure 3.1-2 - Max. Peaking Factor vs. Burnup for BWR Fuel

This page intentionally left blank.

geometric relationship between the TS125 Transportation Cask thermal model and the W74 canister thermal model. Once defined, the Thermal Desktop® program automatically computes the conduction and radiation links between the various thermal nodes representing the W74 canister shell and those representing the interior of the TS125 Transportation Cask.

The canister does not sit symmetrically within the transportation cask, but rests on two 1/8-inch thick guide rails attached to the transportation cask inner shell. Since this configuration results in eccentric positioning of the canister within the cask, the Thermal Desktop® conservatively calculated the gap conductance between the canister shell and the inner shell of the cask as a function of the position around the canister's circumference. The contact conductance[24] between the canister and the guide rails is computed based on the weight of the canister and the area of contact between the canister and the guide rails.

Impact of Fission Gases on the Thermal Performance of the Canister and Cask

The predicted change in gas mixture properties as a function of fission gas concentration is made using the mole fractions of the various constituents of the gas mixture and a complex function of viscosities and molecular weights. The estimation technique is based on the kinetic theory of gases. The evaluation, presented in Section 3.6.3, demonstrates that the fission gas release associated with a 3% fuel rod failure rate for NCT conditions will have no effect on the safety analysis for the FuelSolutions™ W74 canister in the TS125 Transportation Cask. The evaluation also demonstrates that a 100% fuel rod failure rate under accident conditions will have only marginal effects on the predicted temperatures within the W74 canister.

3.4.1.2 Test Thermal Model

In accordance with 10CFR71.41, and as presented herein, detailed thermal analyses of the W74 canister within the transportation cask are performed to demonstrate compliance with the NCT tests specified in 10CFR71.71. As a result, subsequent transportation package or scale model thermal testing is not required. However, thermal acceptance testing of the transportation cask will be performed as discussed in Section 8.1.6 of the FuelSolutions™ TS125 Transportation Cask SAR.[2]

3.4.2 Maximum Temperatures

The FuelSolutions™ W74 design basis thermal load cases are summarized in Table 3.1-1. For the determination of the W74 canister thermal rating, only steady-state NCT hot (case 1) is considered. The combined W74 canister and transportation cask thermal model is exercised using the NCT hot boundary conditions (100°F ambient w/solar) for determination of the W74 canister thermal rating.

The methodology discussed in Section 3.1.3.2 is implemented for the thermal rating case. The design basis canister axial heat profile for Big Rock Point fuel in Figure 3.1-1 is applied as a boundary condition for NCT hot. The allowable material temperatures in Table 3.3-1 are assumed and the total canister heat load (Q_{Total}) is gradually increased until an allowable material

[24] Based on Curve #11 in Figure 8, page 4-19, Rohsenow, Harnett, and Ganic, *Handbook of Heat Transfer Fundamentals*, 2nd Edition, McGraw-Hill, Inc., 1989.

temperature is reached. The W74 canister maximum heat load ratings determined via this approach are presented in Table 3.1-3.

Comparisons of the resulting canister and cask component temperatures with the allowable component temperatures for operations at the qualified W74 canister thermal rating are presented in Table 3.4-1 under the NCT Case 1 column. Figure 3.4-10 presents the sensitivity of the W74 canister and transportation cask components to variations in heat load. As indicated in Table 3.4-1 and Figure 3.4-10, the controlling component for the W74 canister and TS125 cask assembly is the NS-4-FR neutron shielding material. Both the maximum allowable temperature of 338°F and the maximum radial average allowable temperature of 300°F are reached at a heat load of approximately 23.5 kW. The temperatures for the remaining canister and cask components show significant thermal margin at this heat load. A W74 canister heat load of 23.5 kW yields a LHGR of 0.205 kW/inch.

Since the analysis of the FuelSolutions™ TS125 Transportation Cask with a generic canister presented in the FuelSolutions™ TS125 Transportation Cask SAR[2] determined that a maximum canister heat load of 22.0 kW can be accommodated, the thermal rating for the W74 canister is also limited to 22.0 kW for administrative reasons. The higher thermal capacity of the W74 canister/TS125 Transportation Cask combination versus that seen for the generic canister analysis occurs because the design heat generation profile for the W74 canister is spread over a greater axial length due to its double stack of fuel baskets than the heat load profile used for the generic canister. In contrast, the LHGR of 0.192 kW/inch, corresponding to the BRP heat generation profile having a total heat generation of 22.0 kW, is not encompassed by the maximum LHGR of the Q_{max} heat generation profile upon which the FuelSolutions™ TS125 Transportation Cask thermal rating is based. However, as discussed in Section 3.1.3.3, the BRP profile is compliant with the TS125 transportation cask thermal requirements since it does not produce peak temperatures in the cask's inner shell that exceed those calculated for the Q_{max} profile in the FuelSolutions™ TS125 Transportation Cask SAR.

The FuelSolutions™ W74 canister maximum thermal ratings within the TS125 Transportation Cask are applied for the full range of NCT cases presented in Table 3.1-1 in order to determine the resultant transportation package system temperatures. Maximum component temperatures are presented in Table 3.4-1. All W74 canister component temperatures are within their material allowable temperatures for each load case. Note that the maximum temperatures presented in the table are based on operations at the thermal rating for the W74 canister only. A presentation of the bounding transportation cask temperatures at the cask thermal ratings is provided in the FuelSolutions™ TS125 Transportation Cask SAR.[2]

Figure 3.4-11 illustrates the axial temperature distributions at Q_{max} within the SNF assemblies, spacer plates, and canister side wall for NCT hot (i.e., case 1, 100°F w/solar). The temperature distributions are along the hottest portion of the canister and through the top of the cask. The variation in the heat load profile in the double stack of Big Rock Point fuel is clearly visible in the plots. Figure 3.4-12 illustrates a similar distribution, except that the cask temperatures are taken along a radial cut 15° above the bottom of the cask. The presence of the cask's shear block can be clearly seen by its impact on the temperature distribution near the cask's mid-length. Figure 3.4-13 illustrates the associated radial temperature distributions for selected axial

where:

$N_{Cask\ Annulus}$ = Total moles cask annulus backfill gas

$N_{Canister}$ = Total moles canister cavity backfill gas

$N_{SNF\ Fill}$ = Total moles SNF rod fill gas within canister

$N_{SNF\ Fission}$ = Total moles SNF rod fission gas yield (30% released) within canister

R = Ideal Gas Constant (0.0821 atm-liter/gmole-°K)

V_{Cask} = Combined canister and cask cavity free volume (liters)

T_{NCT} = Volume weighted average helium temperature within cask (°K)

The FuelSolutions™ TS125 Transportation Cask MNOP with the W74 canister and 40 GWd/MTU Big Rock Point fuel is 10.7 psig, as presented in Table 3.4-2. Significant margin exists between this calculated MNOP and the transportation cask design pressure of 75 psig. Table 3.4-4 presents the calculated MNOP for each fuel assembly class that may be accommodated in the W74 canister.

3.4.5 Maximum Thermal Stresses

Section 2.3 of this SAR gives thermo-mechanical properties of the W74 canister materials that may cause temperature-induced stresses in the transportation package. Using the temperature distributions determined from the NCT thermal analyses, thermal stress analyses of the FuelSolutions™ W74 canister are presented in Sections 2.6.1 and 2.6.2 of this SAR. The impact of differential thermal expansion on clearances between transportation package components is specifically addressed. These structural analyses demonstrate the ability of the packaging components to maintain positive design margins for all combinations of NCT loads.

3.4.6 Evaluation of Package Performance for Normal Conditions of Transport

The steady-state thermal analysis results demonstrate that the W74 canister, transportation cask, and impact limiter allowable material temperatures under NCT hot environment are met for the maximum W74 canister thermal rating presented in Table 3.1-3. Additionally, the minimum material temperatures under the NCT cold environment with zero decay heat also meet material specifications. The MNOP resulting from the NCT hot environment and conservative assumptions is within the transportation cask maximum design pressure. Therefore, the W74 canister is suitable for transportation of Big Rock Point SNF within the FuelSolutions™ TS125 Transportation Cask.

Analysis results for NCT hot (case 1) shown in Table 3.4-1, Figure 3.4-11 through Figure 3.4-13, and Figure 3.4-16 through Figure 3.4-18 are used for the NCT shock and vibration, and the 1-foot drop structural evaluations presented in Sections 2.6.5 and 2.6.7 of this SAR, respectively. Analysis results for NCT cold (case 3, -20°F) presented in Figure 3.4-14 through Figure 3.4-15, and Figure 3.4-19 through Figure 3.4-21 are also considered in the structural analyses presented in Sections 2.6.5 and 2.6.7 of this SAR.

Table 3.4-1 - FuelSolutions™ W74 Canister Maximum System Temperatures for NCT

Component	NCT Thermal Load Condition[1]			Maximum Allowable Temperature
	Case 1 (100°F/Solar)[2]	Case 3 (-20°F/No Solar)[3]	Case 5 (-40°F/No Solar)	
Peak Fuel Cladding	346.7°C/656.1°F	305.9°C/582.6°F	299.5°C/571.1°F	400°C/752°F
Guide Tube	628°F	547°F	534°F	800°F
Spacer Plates				
Stainless Steel	590°F	507°F	494°F	800°F
Carbon Steel	615°F	532°F	519°F	700°F
Support Tube	599°F	520°F	508°F	700°F
Avg. Canister Gas	528°F	445°F	431°F	N/A
Canister Shell	475°F	389°F	376°F	800°F
Avg. Canister-Cask Gas	379°F	287°F	272°F	N/A
Inner Cask Shell[4]	363°F	273°F	259°F	800°F
Gamma Shield (Lead)[4]				
Maximum	354°F	263°F	248°F	620°F
Bulk Average	334°F	240°F	226°F	620°F
Outer Cask Shell	328°F	227°F	211°F	800°F
NS-4-FR Shield[4,5]				
Max. Radial Avg.	289°F	186°F	169°F	300°F
Bulk Average	261°F	156°F	139°F	300°F
Neutron Shield Jacket[4,6]				
Near Shear Block	284°F	179°F	162°F	350°F
Elsewhere	213°F	108°F	91°F	350°F
Personnel Barrier	139°F	-7°F	-28°F	185°F
Impact Limiter[7]				
Max. Honeycomb	165°F	30°F	10°F	300°F
Bulk Avg. Honeycomb	151°F	14°F	-7°F	200°F
Cask Metallic Seals				
Cask Closure	246°F	137°F	121°F	932°F
Vent & Drain Ports	262°F	154°F	138°F	662°F

Notes:

(1) All temperatures in this table are based on heat loads of 22.0 kW with Big Rock Point Axial Heat Profile.

(2) W74 canister heat load qualification is based on NCT hot conditions.

(3) NCT hot (100°F) and NCT cold (-20°F) conditions with maximum decay heat and no solar apply as initial conditions for the HAC fire evaluation presented in Section 3.5.

(4) Temperatures computed along an axial cut plane that passes through the "rub rails" to capture the peak temperatures noted in the cask. Lower temperatures are noted at the other cask circumference positions.

(5) The solid neutron shield material temperature is presented in two forms: a radial average temperature at the axial location with the highest temperature and as bulk average temperature across the length of the neutron shield. Both averages are limited to 300°F or less for out gas considerations from the material. Per the heat load qualification process illustrated in Figure 3.4-10, the maximum neutron shield material temperature is below 338°F.

(6) A 350°F limit used based on the maximum operating temperature for the epoxy coating. The operating limit for the carbon steel material is 700°F.

(7) A 300°F limit used to provide a 50°F margin below the cure temperature for the thermoset adhesive used in the fabrication of the honeycomb material. A 200°F limit used for bulk average temperature for structural considerations.

(i.e. 45°F), partially as a result of the increased convection within the canister that reduces the thermal stratification, and partially due to the increase in radiation heat transfer occurring at the higher temperature levels. The peak cask component temperatures show an increase in the vicinity of the rub strip due to the decreased heat transfer rate across the canister-cask annulus with a fission gas mixture. However, as evidenced by the temperatures listed in the third column for the side of the cask (i.e., the 90° position on the cask), the component temperatures over the majority of the cask's circumference are near or below those seen for the case with no fission gas release. Furthermore, unless both the fuel rod cladding and the canister shell pressure boundary were to fail, the canister shell and cask component temperatures would show essentially no change from the case that does not consider the influence of fission gases.

In conclusion, the presence of a bounding amount of fission gases within the canister is expected to yield only marginal component temperature increases. Further, both the fuel cladding and the canister pressure boundary must fail to yield this predicted increase in temperature. Therefore, ignoring its potential presence for both the NCT and HAC evaluations of the canister thermal performance is appropriate.

3.6.4 Big Rock Point Mixed-Oxide (MOX) Fuel

The thermal evaluations provided in this chapter address UO_2 9x9 and 11x11 BRP fuel assemblies. The analysis for UO_2 fuel bounds the condition of a FuelSolutions™ W74 canister loaded with any number of MOX fuel assemblies. The BRP MOX fuel assemblies are similar to the UO_2 assemblies with respect to all assembly physical characteristics (including fuel mass, fuel density, fuel rod cladding dimensions, cladding material, rod fill pressures, and active fuel height) except initial fuel material composition. In addition, as discussed in Section 3.6.4.4, the design operating parameters of MOX fuel is equal to or bounded by those for conventional UO_2 fuel assemblies. All existing BRP MOX fuel has a burnup level under 35 GWd/MTIHM and an assembly cooling time of at least 15 years.

3.6.4.1 Heat Generation of BRP MOX Fuel

Assembly heat generation levels are explicitly calculated for BRP MOX fuel using the ORIGEN 2.1 point-depletion code (see Section 5.5.2 of the FuelSolutions™ W74 Canister Storage FSAR[20]). Based on this analysis, the maximum heat generation level for any existing BRP MOX fuel assembly is less than 150 watts/assembly. This is 56% less than the design basis maximum assembly heat generation level of 343.75 watts/assembly that forms the basis of the canister thermal rating given in Table 3.1-3.

3.6.4.2 Axial Heat Generation Profile of BRP MOX Fuel

The design basis axial heat generation profile discussed in Section 3.1.3 of this SAR is applicable to both MOX and UO_2 BRP fuel assemblies. The physical dimensions (such as active fuel height) of the MOX assemblies are the same as those of the corresponding UO_2 assemblies. Furthermore, the MOX and UO_2 fueled BRP assemblies are irradiated in the same reactor core, often in close proximity to each other, and they have similar linear heat ratings, maximum clad operating temperatures, etc. The BRP MOX fuel assemblies also contain a large number of UO_2

fuel rods around their periphery. For these reasons, the axial heat generation profile is expected to be very similar for BRP UO_2 and MOX assemblies.

3.6.4.3 Effective Thermal Conductivity of BRP MOX Fuel

As discussed in Section 3.4.1 of this SAR, the intact UO_2 fuel assembly is modeled as a homogenous mass that has an effective radial and axial conductivity. Given that the cladding dimensions (i.e., diameter and thickness), the number of fuel rods, and the fuel rod pitch are essentially the same for UO_2 and MOX fuel assemblies, the only significant difference between the UO_2 and MOX assembly types is the fuel material within the fuel rods. However, the fuel material does not contribute significantly to the overall axial or radial assembly conductivity[46] because the fuel material conductivity is lower than that of the fuel rod cladding. Additionally, there are potential gaps between the individual fuel pellets and between the fuel pellets and the cladding. With respect to the effective radial assembly conductivity, the majority of the thermal resistance occurs between the fuel rods, as opposed to within or across the fuel rods.

The temperature difference across the individual fuel rods is very small, even if only conduction through the cladding is considered. Therefore, the fuel material's thermal properties are conservatively neglected in the methodology used to compute the fuel assembly's axial and effective radial thermal conductivity (see Section 3.4.1). As such, the calculated axial and radial conductivities for UO_2 and MOX BRP fuel are the same.

3.6.4.4 Allowable Cladding Temperature for BRP MOX Fuel

Based on proprietary data in Jersey Nuclear and Exxon Nuclear design reports, the design operating parameters of MOX fuel assemblies used at Big Rock Point are equal to or bounded by those for conventional UO_2 fuel assemblies. As such, the bounding operational temperature (e.g., in-reactor) experience of the two fuel rod configurations are similar. Further, since the 35 GWd/MTU burnup value of the BRP MOX fuel is below the design basis 40 GWd/MTU burnup for the conventional BRP fuel, the MOX fuel internal rod pressures and operating temperature effects will be bounded by those for the conventional BRP fuel.

The peak BRP fuel rod pressure is based on a generated fission gas quantity of about 8 moles per fuel assembly. The data presented in Table 3.1-5 assume a 30% release fraction; therefore, the total fission gas quantity available for release is about 2.4 moles per assembly.

The generated fission gas inventory for all BRP MOX fuel is less than 6 moles per assembly due to its lower burnup value (under 35 GWd/MTU versus a design basis UO_2 fuel burnup of 40 GWd/MTU). Assuming a 30% release fraction, the quantity of fission gas available for release would be less than 1.8 moles per assembly. Therefore, the MOX fission gas available for release is bounded. It is also noted that the longer assembly cooling time (a minimum of 15 years) yields lower rod temperatures and, thus, rod pressures.

Given that other parameters such as cladding dimensions, gas plenum volume, and fill gas pressure are similar for the MOX and UO_2 assemblies, and given the lower MOX fuel internal

[46] Manteufel, R. D. and Todreas, N. E., *Effective Thermal Conductivity and Edge Conductance Model for a Spent-Fuel Assembly*, Nuclear Technology, Vol. 105, March 1994.

rod pressure, the cladding stress levels determined for design basis BRP UO_2 fuel at any given temperature are bounding for BRP MOX fuel. Because the cladding stress levels are lower for MOX fuel, the allowable cladding temperature based on the creep methodology is bounding for all BRP MOX fuel.

3.6.4.5 Canister Internal Pressure for BRP MOX Fuel

Since the BRP MOX fuel assemblies have lower fission gas quantities and, therefore, lower internal rod pressures than the design basis BRP assemblies, the canister internal pressures calculated in Sections 3.4.4.3 and 3.5.4 of this SAR are bounding for a canister containing any amount of MOX fuel.

3.6.4.6 Thermal Summary for BRP MOX Fuel

BRP MOX fuel assemblies have an axial heat generation profile, an effective assembly thermal conductivity (axial and radial), and an assembly heat generation decay curve that are similar to those of BRP design basis (UO_2 fueled) assemblies. Furthermore, the BRP MOX fuel assemblies have lower internal rod pressures, 56% lower heat generation levels due to lower burnup level, and much longer cooling times than the BRP design basis assemblies. For these reasons, BRP MOX fuel assemblies will produce lower peak fuel cladding temperatures (when loaded into the canister), while having fuel rod cladding allowable temperatures that are at least as high as those of BRP design basis fuel assemblies.

As such, the thermal evaluations for normal and accident conditions of transportation presented in Sections 3.4 and 3.5 of this SAR are valid and bounding for canisters containing BRP MOX fuel assemblies. Therefore, it is concluded that all existing BRP MOX fuel assemblies are thermally qualified for loading into the FuelSolutions™ W74 canister and no further thermal or assembly heat generation calculations need to be performed.

3.6.5 Big Rock Point Damaged Fuel

The thermal evaluations provided in this chapter assume intact fuel assemblies. However, the analysis bounds the assumption of a canister loaded with up to eight damaged fuel assemblies. Damaged includes fuel rod damage in excess of hairline cracks or pinhole leaks. Fuel assemblies with damaged grid spacers (defined as damaged to a degree where fuel rod structural integrity cannot be assured, or where grid spacers have shifted vertically from their design position) will also be stored in damaged fuel cans. The relatively minor nature of the fuel assembly damage contained within this definition supports the basic assumption that the fuel assemblies to be placed in the damaged fuel cans have the basic geometric configuration of an undamaged fuel assembly and are expected to retain this geometry throughout normal and accident transportation events.

The evaluation for damaged fuel assemblies includes an assessment of the thermal effects imposed by the presence of the damaged fuel can. The effect of the damaged fuel can on the overall (smeared) heat transfer coefficient of the damaged fuel assemblies is deemed negligible. Because the damaged fuel has the same design heat generation rate as intact fuel, the steady-state effect would be a slight increase in the damaged fuel cladding temperatures and would not result in a change in the spacer plate temperature distribution (see Section 3.6.5.5).

Since it is not possible to definitively know the full extent of damage to each fuel assembly, the evaluation for damaged fuel also includes an assessment of the predicted temperatures within the damaged fuel can and within the W74 canister in response to a potential reconfigured fuel assembly within the damaged fuel can(s).

3.6.5.1 Heat Generation of BRP Damaged Fuel

Assembly heat generation levels are calculated for BRP damaged UO_2 and damaged MOX fuel assemblies using the ORIGEN 2.1 point-depletion code (see Section 5.5.2 of the FuelSolutions™ W74 Canister Storage FSAR[20]). The maximum heat generation level permitted for any BRP damaged fuel assembly to be loaded into the FuelSolutions™ W74 canister is equal to the design basis maximum assembly heat generation level of 343.75 watts/assembly. Per Section 3.6.4.1, damaged MOX fuel assemblies have heat loads that are 56% less than those of the design basis assembly. The design basis heat generation rate forms the basis of the canister thermal rating given in Section 3.1.4 of this SAR.

3.6.5.2 Axial Heat Generation Profile of BRP Damaged Fuel

The design basis axial heat generation profile discussed in Section 3.1.3 is applicable for damaged and intact UO_2 and MOX BRP fuel assemblies. The physical dimensions (such as active fuel height) of the damaged fuel assemblies are the same as those of the corresponding intact assemblies. The damaged fuel assemblies are also irradiated in the same reactor core as the intact fuel assemblies. Therefore, for given burnup and cooling time, the BRP damaged fuel axial heat generation profile is the same as that for the BRP intact fuel assemblies.

The axial heat generation profile associated with a potential reconfigured damaged fuel assembly is addressed in the following section.

3.6.5.3 Effective Thermal Conductivity of BRP Damaged Fuel

Given the level of damage expected for BRP damaged fuel, the thermal resistance between the damaged fuel can and the damaged fuel assembly is expected to be encompassed by that used for the evaluation of the intact fuel assemblies. As discussed in Section 3.2.2, the fuel assembly is modeled as a homogenous mass that has an effective radial and axial conductivity. The effective radial and axial conductivities are assumed to be the same for both the UO_2 and MOX damaged fuel assemblies (see Section 3.6.4.3). A mis-positioned grid spacer, or damage in the excess of a pinhole leak or hairline crack in a few rods will not affect the overall pin-to-pin heat transfer via radiation or conduction/convection that characterizes an intact fuel assembly. Also, the loss of a rod's internal gas pressure due to a defect will not affect the computed effective conductivity for the assembly because the presence of both the fill gas and the fuel material is conservatively ignored by the methodology used (see Section 3.2.2).

Since damaged rods will have released their gas prior to placement within the canister, there will be no introduction of fission gas from the damaged fuel into the canister atmosphere. Further, analysis has shown that the presence of fill gas constituents within the canister environment will not adversely affect the overall heat transfer rates.