



ENERGYSOLUTIONS
Spent Fuel Division

April 10, 2007
SFD/NRC 07-005
Docket No. 72-1007
File No. WEP-09

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: Transmittal of the VSC-24 Ventilated Storage Cask System Final Safety Analysis Report (FSAR) Biennial Update

References: 1) VSC-24 Ventilated Storage Cask System Final Safety Analysis Report, Revision 7.
2) Letter from EnergySolutions SFD to U.S. Nuclear Regulatory Commission, Subject: Biennial 72.48 Report for the Ventilated Storage Cask (VSC-24) System, Letterbook No. SFD/NRC 07-002, March 22, 2007.

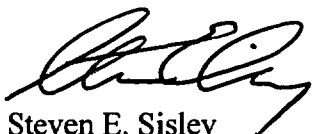
Dear Sir or Madam:

In accordance with the requirements of 10 CFR 72.248, EnergySolutions Spent Fuel Division, Inc. (EnergySolutions SFD) has updated the VSC-24 Ventilated Storage Cask System Final Safety Analysis Report (FSAR) (Reference 1) to incorporate all changes to the implemented within the previous 24 month period. The changes included in the FSAR update were implemented in accordance with the EnergySolutions SFD Quality Assurance Program. A summary of the changes is attached. As stated in the Reference 2 letter, no changes have been made to the VSC-24 Ventilated Storage Cask System under the provisions of 10 CFR 72.48 within the previous 24-month period that have not been previously submitted to NRC.

Enclosed are two copies of the updated revision of the VSC-24 Ventilated Storage Cask System FSAR. In accordance with the requirements of 10 CFR 72.248(c), the transmittal includes a complete set of replacement pages, with changes indicated in the margin, and a list of effective pages.

Should you or any member of your staff have questions, please contact the undersigned at (408) 558-3509.

Sincerely,



Steven E. Sisley
Licensing/Regulatory Compliance Manager

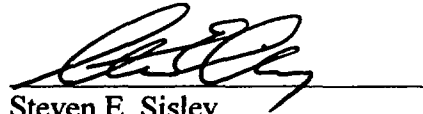
Attachment: List of Changes for VSC-24 Ventilated Storage Cask System FSAR, Revision 7.

Enclosure: Replacement pages for “VSC-24 Ventilated Storage Cask System Final Safety Analysis Report,” Revision 7 (2 copies)

cc) Jill Caverly, SFST w/ Attachment and Enclosure

CERTIFICATION

Steven E. Sisley states that he is the Licensing/Regulatory Compliance Manager at EnergySolutions Spent Fuel Division, Inc. and that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission the information attached hereto. Mr. Sisley certifies that the information accurately presents changes made since the previous revision of the VSC-24 Ventilated Storage Cask System Final Safety Analysis Report.

A handwritten signature in black ink, appearing to read 'Sisley', is written over a horizontal line.

Steven E. Sisley
Licensing/Regulatory Compliance Manager
EnergySolutions Spent Fuel Division, Inc.

List of Changes for VSC-24 Ventilated Storage Cask System FSAR, Revision 7

Section	Page(s)	Description
1.3	1-8	Editorial correction.
13.0	13-1	Editorial correction.

Docket 72-1007
Revision 7

Final Safety Analysis Report
For the
VSC-24 Ventilated Storage Cask System

Prepared by:

EnergySolutions Spent Fuel Division, Inc.
Campbell, California

April 2007

TABLE OF CONTENTS

1.0 GENERAL DESCRIPTION	1-1
1.1 INTRODUCTION.....	1-1
1.2 GENERAL DESCRIPTION OF THE STORAGE CASK	1-2
1.2.1 CASK SYSTEM CHARACTERISTICS.....	1-2
1.2.1.1 Description of the MSB	1-3
1.2.1.2 Description of the VCC	1-5
1.2.1.3 Description of the MTC.....	1-6
1.2.1.4 Description of the Roller Skid	1-7
1.2.1.5 Transfer Trailer	1-7
1.2.2 OPERATIONAL FEATURES.....	1-7
1.2.3 CASK CONTENTS.....	1-8
1.3 IDENTIFICATION OF AGENTS AND CONTRACTORS.....	1-8
1.4 GENERIC CASK ARRAYS.....	1-9
1.5 SUPPLEMENTAL DATA.....	1-22
2.0 PRINCIPAL DESIGN CRITERIA	2-1
2.1 IRRADIATED FUEL TO BE STORED.....	2-1
2.2 DESIGN CRITERIA FOR ENVIRONMENTAL CONDITIONS AND NATURAL PHENOMENA.....	2-2
2.2.1 ENVIRONMENTAL TEMPERATURES.....	2-2
2.2.2 TORNADO AND WIND LOADINGS	2-3
2.2.3 WATER LEVEL (FLOOD) DESIGN	2-4
2.2.4 SNOW AND ICE LOADINGS.....	2-4
2.2.5 SEISMIC DESIGN.....	2-4
2.2.6 COMBINED LOAD CRITERIA	2-5
2.2.6.1 Load Combinations and Design Strength - Concrete Cask.....	2-5
2.2.6.2 Load Combinations and Design Strength - MSB Steel Vessel.....	2-5
2.2.6.3 Design Strength - MSB Transfer Cask	2-6
2.3 SAFETY PROTECTION SYSTEMS	2-6
2.3.1 GENERAL.....	2-6
2.3.2 PROTECTION BY MULTIPLE CONFINEMENT BARRIERS AND SYSTEMS.....	2-7

TABLE OF CONTENTS

(continued)

2.3.2.1	Confinement Barriers and Systems	2-7
2.3.2.2	Ventilation Off-Gas.....	2-8
2.3.3	PROTECTION BY EQUIPMENT AND INSTRUMENTATION SELECTION	2-8
2.3.3.1	Equipment	2-8
2.3.3.2	Instrumentation	2-8
2.3.4	NUCLEAR CRITICALITY SAFETY	2-9
2.3.5	RADIOLOGICAL PROTECTION	2-9
2.3.5.1	Access Control	2-9
2.3.5.2	Shielding.....	2-9
2.3.5.3	Radiological Alarm Systems	2-10
2.3.6	FIRE AND EXPLOSION PROTECTION	2-10
2.3.7	LIGHTNING.....	2-10
2.4	DECOMMISSIONING CONSIDERATIONS.....	2-10
3.0	STRUCTURAL EVALUATION	3-1
3.1	STRUCTURAL DESIGN.....	3-1
3.1.1	DISCUSSION	3-1
3.1.2	DESIGN CRITERIA	3-2
3.2	WEIGHTS AND CENTERS OF GRAVITY	3-2
3.3	MECHANICAL PROPERTIES OF MATERIALS.....	3-2
3.4	GENERAL STANDARDS FOR CASKS.....	3-3
3.4.1	CHEMICAL AND GALVANIC REACTIONS.....	3-3
3.4.2	POSITIVE CLOSURE	3-3
3.4.3	LIFTING DEVICES	3-3
3.4.3.1	VSC Bottom Lift.....	3-4
3.4.3.2	MSB Lift	3-4
3.4.3.3	MTC Lift	3-5
3.4.4	VSC COMPONENTS UNDER NORMAL OPERATING LOADS.....	3-7
3.4.4.1	MSB Analysis	3-7
3.4.4.1.1	MSB Thermal Stress Analysis.....	3-8
3.4.4.1.2	Dead Weight Load Analysis.....	3-9
3.4.4.1.3	MSB Internal Pressure Analysis.....	3-12

TABLE OF CONTENTS

(continued)

3.4.4.1.4	MSB Handling Stresses	3-13
3.4.4.1.5	MSB Load Combination.....	3-14
3.4.4.1.6	MSB Pressure Test	3-15
3.4.4.2	VCC Analysis.....	3-15
3.4.4.2.1	VCC Dead Load	3-16
3.4.4.2.2	VCC Live Load.....	3-16
3.4.4.2.3	VCC Thermal Stresses.....	3-16
3.4.4.3	MTC Stress Calculations and Comparison with Allowables.....	3-18
3.4.5	COLD.....	3-18
3.4.5.1	MSB	3-18
3.4.5.2	MTC	3-19
3.5	FUEL RODS.....	3-19
4.0	THERMAL EVALUATION	4-1
4.1	DISCUSSION.....	4-1
4.2	SUMMARY OF THERMAL PROPERTIES OF MATERIALS.....	4-2
4.3	TECHNICAL SPECIFICATION OF COMPONENTS	4-2
4.4	THERMAL EVALUATION FOR NORMAL STORAGE CONDITIONS.....	4-3
4.4.1	THERMAL MODELS.....	4-3
4.4.1.1	Air Flow and Temperature Calculation	4-3
4.4.1.2	VCC Body and MSB Exterior Thermal Model.....	4-5
4.4.1.2.1	Heat Transfer Modes	4-5
4.4.1.2.2	VCC Thermal Hydraulic Model	4-6
4.4.1.2.3	Radiation.....	4-6
4.4.1.2.4	VCC Convections	4-6
4.4.1.2.5	VCC Modeling Assumptions.....	4-7
4.4.1.3	MSB Thermal-Hydraulics.....	4-7
4.4.1.3.1	MSB Heat Transfer Modes	4-7
4.4.1.3.2	MSB Thermal Hydraulic Model.....	4-8
4.4.1.3.3	MSB Fuel Heat Source Strength.....	4-8
4.4.1.3.4	MSB Heat Transfer Properties.....	4-8
4.4.1.3.5	MSB Model Assumptions.....	4-9
4.4.1.4	Transfer Cask Model.....	4-9

TABLE OF CONTENTS

(continued)

4.4.1.4.1	MTC Heat Transfer Modes.....	4-9
4.4.1.4.2	MTC Thermal Hydraulic Model.....	4-10
4.4.1.4.3	MSB Vacuum Cover Gas Thermal Hydraulic Model.....	4-11
4.4.1.5	Determination of VCC Surface Heat Transfer Coefficient.....	4-11
4.4.1.6	Determination of Fuel Effective Thermal Conductivities.....	4-12
4.4.2	TEST MODEL.....	4-13
4.4.3	MAXIMUM TEMPERATURES.....	4-13
4.4.4	MINIMUM TEMPERATURES.....	4-13
4.4.5	MAXIMUM INTERNAL PRESSURE.....	4-13
4.4.6	MAXIMUM THERMAL STRESSES.....	4-14
4.4.7	EVALUATION OF CASK PERFORMANCE FOR NORMAL CONDITIONS OF STORAGE.....	4-14
5.0	SHIELDING EVALUATION.....	5-1
5.1	DISCUSSION AND RESULTS.....	5-1
5.2	SOURCE SPECIFICATION.....	5-2
5.2.1	GAMMA SOURCE DESCRIPTION.....	5-3
5.2.1.1	Fuel Gamma Source.....	5-3
5.2.1.2	Assembly Hardware Gamma Sources.....	5-4
5.2.1.3	Axial Gamma Source Strength Profile.....	5-7
5.2.2	NEUTRON SOURCE DESCRIPTION.....	5-8
5.2.2.1	Total Neutron Source Strength.....	5-8
5.2.2.2	Axial Neutron Source Strength Profile.....	5-9
5.3	MODEL SPECIFICATION.....	5-11
5.3.1	STORAGE CASK MODEL GEOMETRY.....	5-11
5.3.1.1	Storage Cask Bulk Model Geometry.....	5-11
5.3.1.2	MSB Interior Model Geometry.....	5-11
5.3.1.2.1	Primary Shielding Analysis Model.....	5-11
5.3.1.2.2	Supplementary Gamma Analysis Model.....	5-12
5.3.1.3	Inlet and Outlet Duct Model Geometry.....	5-12
5.3.2	TRANSFER CASK MODEL GEOMETRY.....	5-13
5.3.3	SHIELD REGIONAL DENSITIES.....	5-14

TABLE OF CONTENTS

(continued)

5.4	SHIELDING EVALUATION	5-15
5.4.1	SHIELDING ANALYSIS CODE	5-15
5.4.2	MCNP AREA DETECTORS.....	5-15
5.4.3	FLUX-TO-DOSE CONVERSION FACTORS.....	5-16
5.4.4	SUPPLEMENTARY SHIELDING ANALYSES	5-16
5.5	SUPPLEMENTARY ANALYSES	5-17
5.5.1	ALTERNATIVE FUEL PARAMETER EVALUATION	5-17
5.5.2	EVALUATION OF ASSEMBLIES WITH HIGH HARDWARE COBALT QUANTITIES.....	5-20
6.0	CRITICALITY EVALUATION.....	6-1
6.1	Criticality Design Criteria and Features	6-1
6.2	Fuel Specification	6-2
6.3	Model Specification.....	6-4
6.3.1	Configuration	6-4
6.3.2	Material Properties.....	6-7
6.4	Criticality Analysis.....	6-8
6.4.1	Computer Programs	6-8
6.4.2	Multiplication Factor.....	6-9
6.4.2.1	Part 1 of Methodology: Base Case Identification	6-10
6.4.2.2	Part 2 of Methodology: Sensitivity Analysis	6-11
6.4.2.3	Part 3 of Methodology: Partial Flooding Analysis.....	6-12
6.4.2.4	Results	6-13
6.4.2.5	Compliance with Requirements.....	6-17
6.4.2.6	Range of Validity	6-17
6.4.2.7	Summary of Conservatism.....	6-17
6.4.2.8	Limitations or Special Requirements.....	6-18
6.4.3	Benchmark Comparisons.....	6-19
6.4.3.1	Methodology of Maximum Allowable K_{eff} Calculation (USL method).....	6-20
6.4.3.2	VSC-24 USL Calculations.....	6-23
7.0	CONFINEMENT.....	7-1
7.1	CONFINEMENT BOUNDARY	7-1

TABLE OF CONTENTS

(continued)

7.1.1	CONFINEMENT VESSEL.....	7-1
7.1.2	CONFINEMENT (MSB) PENETRATIONS.....	7-1
7.1.3	SEALS AND WELDS.....	7-2
7.1.3.1	Fabrication.....	7-2
7.1.3.2	Welding Specifications.....	7-3
7.1.3.3	Testing, Inspection, and Examination.....	7-3
7.1.4	CLOSURE.....	7-3
7.1.5	CONFINEMENT BOUNDARY MONITORING.....	7-3
7.2	REQUIREMENTS FOR NORMAL AND OFF-NORMAL CONDITIONS OF STORAGE.....	7-4
7.2.1	RELEASE OF RADIOACTIVE MATERIAL.....	7-4
7.2.2	PRESSURIZATION OF CONFINEMENT VESSEL.....	7-6
7.3	CONFINEMENT REQUIREMENTS FOR HYPOTHETICAL ACCIDENT CONDITIONS.....	7-7
7.3.1	FISSION GAS PRODUCTS.....	7-7
7.3.2	RELEASE OF CONTENTS.....	7-7
8.0	OPERATING PROCEDURES.....	8-1
8.1	PROCEDURES FOR LOADING THE CASK.....	8-1
8.2	PROCEDURES FOR UNLOADING THE CASK.....	8-3
8.3	PREPARATION OF THE CASK FOR ON-SITE TRANSPORT.....	8-3
8.4	SUPPLEMENTAL DATA.....	8-4
9.0	ACCEPTANCE TEST AND MAINTENANCE PROGRAM.....	9-1
9.1	ACCEPTANCE TEST.....	9-1
9.1.1	VISUAL INSPECTION.....	9-1
9.1.1.1	Fabrication Inspections.....	9-1
9.1.1.2	Inspection Prior to Use.....	9-2
9.1.2	STRUCTURAL AND PRESSURE TEST.....	9-2
9.1.3	TEST OF THE FIRST VSC PLACED IN SERVICE.....	9-3
9.2	MAINTENANCE PROGRAM.....	9-3
10.0	RADIATION PROTECTION.....	10-1

TABLE OF CONTENTS

(continued)

10.1 ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES ARE AS LOW AS IS REASONABLY ACHIEVABLE (ALARA).....	10-1
10.1.1 POLICY CONSIDERATIONS.....	10-1
10.1.2 DESIGN CONSIDERATIONS.....	10-1
10.1.3 OPERATIONAL CONSIDERATIONS.....	10-1
10.2 RADIATION PROTECTION DESIGN FEATURES.....	10-2
10.2.1 DESIGN BASIS FOR NORMAL CONDITIONS.....	10-2
10.2.2 DESIGN BASIS FOR ACCIDENT CONDITIONS.....	10-2
10.3 ESTIMATED ON-SITE COLLECTIVE DOSE ASSESSMENT.....	10-2
10.3.1 ESTIMATED OCCUPANCY REQUIREMENTS.....	10-2
10.3.2 DOSE RATES.....	10-2
10.3.3 ESTIMATED MAN-REM EXPOSURES FOR OPERATION, MAINTENANCE, AND INSPECTION OF THE EQUIPMENT.....	10-3
10.4 ESTIMATED OFF-SITE COLLECTIVE DOSE ASSESSMENT.....	10-4
10.4.1 OFF-SITE DOSE FOR NORMAL AND OFF-NORMAL OPERATIONS.....	10-5
10.4.2 OFF-SITE DOSE FOR ACCIDENT CONDITIONS.....	10-6
11.0 ACCIDENT ANALYSIS.....	11-1
11.1 OFF-NORMAL EVENTS.....	11-1
11.1.1 OFF-NORMAL, SEVERE ENVIRONMENTAL CONDITIONS.....	11-1
11.1.1.1 Cause of Event.....	11-1
11.1.1.2 Detection.....	11-2
11.1.1.3 Analysis.....	11-2
11.1.1.4 Corrective Actions.....	11-3
11.1.2 BLOCKAGE OF ONE-HALF OF THE AIR INLETS.....	11-3
11.1.2.1 Cause.....	11-3
11.1.2.2 Detection.....	11-3
11.1.2.3 Analysis, Effects, and Consequences.....	11-3
11.1.2.4 Corrective Actions.....	11-4
11.1.3 INTERFERENCE DURING MSB LOWERING FROM TRANSFER CASK INTO CONCRETE CASK.....	11-4
11.1.3.1 Cause of Event.....	11-4

TABLE OF CONTENTS

(continued)

11.1.3.2	Detection	11-4
11.1.3.3	Analysis of Effects and Consequences.....	11-4
11.1.3.4	Corrective Actions	11-5
11.1.4	SMALL RELEASE OF RADIOACTIVE PARTICULATES FROM THE MSB EXTERIOR.....	11-5
11.1.4.1	Cause of Event	11-5
11.1.4.2	Detection	11-5
11.1.4.3	Analysis of Effects and Consequences.....	11-6
11.1.4.4	Corrective Actions	11-6
11.1.5	MSB OFF-NORMAL HANDLING LOAD.....	11-6
11.1.5.1	Cause of Event	11-6
11.1.5.2	Detection	11-7
11.1.5.3	Analysis.....	11-7
11.1.6	OFF-NORMAL PRESSURIZATION	11-8
11.1.6.1	Cause of Pressurization.....	11-8
11.1.6.2	Analysis of Off-Normal Pressurization	11-8
11.1.6.3	Radiological Consequences	11-9
11.2	ACCIDENTS.....	11-9
11.2.1	MAXIMUM ANTICIPATED HEAT LOAD.....	11-9
11.2.1.1	Cause of Accident	11-9
11.2.1.2	Accident Analysis	11-9
11.2.1.3	Accident Dose Calculation	11-10
11.2.2	MSB DROP ACCIDENT.....	11-10
11.2.2.1	Cause of Accident	11-10
11.2.2.2	Accident Analysis	11-10
11.2.2.3	Accident Dose Calculation	11-12
11.2.3	TORNADO	11-12
11.2.3.1	Cause of a Tornado	11-12
11.2.3.2	Tornado Accident Analysis	11-12
11.2.3.3	Tornado Accident Dose Calculations	11-15
11.2.4	FLOOD.....	11-16
11.2.4.1	Causes of Flood.....	11-16
11.2.4.2	Flood Analysis	11-16

TABLE OF CONTENTS

(continued)

11.2.4.3 Flood Dose Calculations11-17

11.2.5 EARTHQUAKE EVENT.....11-17

 11.2.5.1 Cause of Earthquake11-17

 11.2.5.2 Earthquake Analysis11-17

 11.2.5.3 Accident Dose Calculation11-18

11.2.6 ACCIDENT PRESSURIZATION11-18

 11.2.6.1 Cause of Pressurization.....11-18

 11.2.6.2 Analysis of Pressurization Accident.....11-19

 11.2.6.3 Radiological Consequences11-20

11.2.7 FULL BLOCKAGE OF AIR INLETS11-20

 11.2.7.1 Cause11-20

 11.2.7.2 Detection11-20

 11.2.7.3 Analysis of Event.....11-20

 11.2.7.4 Consequences of Event.....11-21

12.0 OPERATING CONTROLS AND LIMITS 12-1

 12.1 PROPOSED OPERATING CONTROLS AND LIMITS.....12-1

 12.2 DESIGN FEATURES12-1

 12.3 ADMINISTRATIVE CONTROLS12-2

 12.4 CONDITIONS FOR CASK USE AND TECHNICAL SPECIFICATIONS.....12-2

13.0 QUALITY ASSURANCE..... 13-1

14.0 REFERENCES 14-1

 14.1 Section References.....14-1

 14.2 Other References.....14-4

A APPENDIX A - FUEL ASSEMBLY REGION EFFECTIVE THERMAL CONDUCTIVITY A-1

 A.1 INTRODUCTIONA-1

 A.2 DESIGN INPUT AND ASSUMPTIONS.....A-1

 A.2.1 ASSUMPTIONS.....A-1

 A.2.2 INPUTA-1

 A.3 CALCULATIONSA-1

TABLE OF CONTENTS

(continued)

A.3.1	APPLICATION OF THE WOOTEN-EPSTEIN CORRELATION.....	A-1
A.3.2	EXAMINATION OF CASK TEST DATA AND PRE AND POST TEST ANALYSIS USING HYDRA AND COBRA.....	A-3
A.3.3	MODEL TN-24 TEST.....	A-4
A.4	CONCLUSIONS.....	A-5
B	APPENDIX B - OPTIONAL CASK TRANSPORTER AND VSC LIFTING LUGSB-1	
B.1	INTRODUCTION.....	B-1
B.2	TRANSPORTER.....	B-1
B.3	VSC LIFTING LUGS.....	B-1
C	APPENDIX C - FUEL INERT DRY STORAGE TEMPERATURE LIMITS.....	C-1
C.1	INTRODUCTION.....	C-1
C.2	ANALYSIS.....	C-1
C.3	RESULTS AND CONCLUSIONS.....	C-2
D	APPENDIX D - EFFECTIVE THERMAL CONDUCTIVITIES FOR WIDE AND NARROW AREAS WITHIN THE MSB.....	D-1
D.1	INTRODUCTION.....	D-1
D.2	ANALYSIS.....	D-1
D.3	RESULTS AND CONCLUSIONS.....	D-2
E	APPENDIX E - NOT USED.....	E-1
F	APPENDIX F - SPECIFICATION VMSB-98-001.....	F-1

LIST OF TABLES

Table 1.2-1 - Summary of VSC-24 System Design Criteria (2 pages).....	1-10
Table 1.2-2 - Major Physical Design Characteristics for the 24 Assembly MSB	1-12
Table 1.2-3 - MSB Fabrication Summary.....	1-13
Table 1.2-4 - Major Physical Design Parameters for the 24 Assembly VCC	1-14
Table 1.2-5 - VCC Construction Summary	1-15
Table 1.2-6 - Major Physical Design Parameters for the 24 Assembly MTC.....	1-16
Table 1.2-7 - Exceptions to ASME Section III Requirements for the MSB (2 pages).....	1-17
Table 2.0-1 - VCC Design Parameters (2 pages).....	2-12
Table 2.0-2 - MSB Design Parameters (2 pages)	2-14
Table 2.0-3 - MTC Design Parameters (2 pages)	2-16
Table 2.0-4 - Design Configurations for Calculations (2 pages).....	2-18
Table 2.1-1 - Principal Design Parameters for PWR Fuel Assemblies to be Stored in a Ventilated Storage Cask	2-20
Table 2.2-1 - Tornado-Generated Missiles	2-21
Table 2.2-2 - Load Combinations for the VSC Concrete Cask	2-22
Table 2.2-3 - MSB Load Combinations.....	2-23
Table 2.2-4 - Structural Design Criteria for Steel Components Used in the Multi-Assembly Sealed Basket	2-24
Table 2.3-1 - Radioactivity Confinement Barriers and Systems of the VSC System	2-25
Table 3.2-1 - VSC System Weights and Centers of Gravity	3-20
Table 3.3-1 - Mechanical Properties of Steels Used in the VSC.....	3-21
Table 3.4-1 - MSB-24 Design Loadings.....	3-22
Table 3.4-2 - Summary of Maximum VSC Temperatures for Structural Evaluation.....	3-23
Table 3.4-3 - Summary of Results MSB Storage Sleeve Assembly Thermal Stresses	3-24
Table 3.4-4 - Summary of Maximum MSB Body Thermal Stresses (ksi)	3-25
Table 3.4-6 - VCC Structural Load Combination Evaluation	3-28
Table 3.4-7 - Summary of Maximum VCC Thermal Stresses 75°F Ambient Air, Normal Operation	3-29

LIST OF TABLES

(continued)

Table 4.1-1 - Summary of VSC System Thermal Hydraulics Evaluation.....	4-15
Table 4.2-1 - Thermal Properties.....	4-16
Table 4.3-1 - Condition Categories and Temperature Limits for Concrete.....	4-17
Table 4.4-1 - Summary of VSC Cooling Air Flow Analysis.....	4-18
Table 5.1-1 - Storage Cask Exterior Dose Rates	5-24
Table 5.1-2 - Transfer Cask Exterior Dose Rates.....	5-25
Table 5.2-1 - Assembly Fuel Zone Gamma Source Strengths.....	5-26
Table 5.2-2 - Assembly Hardware Source Strength Calculation.....	5-27
Table 5.2-3 - Assembly Non-Fuel Zone Hardware Gamma Source Strengths.....	5-28
Table 5.2-4 - Gamma and Neutron Axial Source Strength Profiles	5-29
Table 5.3-1 - VSC-24 Cask Material Elemental Compositions.....	5-30
Table 5.3-2 - MSB Interior Homogenized Material Elemental Densities	5-31
Table 5.4-1 - Gamma Flux-to-Dose Conversion Factors (ANSI/ANS-6.1.1-1977).....	5-32
Table 5.4-2 - Neutron Flux-to-Dose Conversion Factors (ANSI/ANS-6.1.1-1977)	5-33
Table 5.5-1 - VSC-24 Minimum Required Assembly Cooling Time vs. Burnup and Enrichment.....	5-34
Table 6.1-1 - MSB and MTC Component Dimensions (Actual and Modeled).....	6-25
Table 6.2-1(a) - Fuel Assembly Class Characterization Parameters	6-26
Table 6.2-1(b) - Fuel Assembly Class Characterization Parameters	6-27
Table 6.3-1 - MSB and MTC Material Compositions	6-28
Table 6.3-2 - UO ₂ Fuel Compositions	6-29
Table 6.4-1 - Criticality Analysis Results for the B&W 15x15 Assembly Class ^[1,2]	6-30
Table 6.4-2 - Criticality Analysis Results for the W 14x14 Assembly Class ^[1,2]	6-31
Table 6.4-3 - Criticality Analysis Results for the W 15x15 Assembly Class ^[1]	6-32
Table 6.4-4 - Criticality Analysis Results for the W 17x17 Assembly Class ^[1,2]	6-33
Table 6.4-5 - Criticality Analysis Results for the CE 15x15A Assembly Class ^[1]	6-35

LIST OF TABLES

(continued)

Table 6.4-6 - Criticality Analysis Results for the CE 15x15B Assembly Class ^[1,2]	6-36
Table 6.4-7 - Criticality Analysis Results for the CE 15x15C Assembly Class ^[1,2]	6-38
Table 6.4-8 - Criticality Analysis Results for the CE 16x16 Assembly Class ^[1]	6-40
Table 6.4-9 - Results of Criticality Sensitivity Analyses (Δk_{eff}) ¹	6-41
Table 6.4-10 - Characteristic Parameters of VSC-24 Critical Benchmarks (2 pages).....	6-42
Table 6.4-11 - USL Equation Parameter Values.....	6-44
Table 6.4-12 - USL Functions Applicable to the VSC-24 System (2 pages).....	6-45
Table 6.4-13 - Range of Physical Parameter Values for VSC-24 Criticality Evaluations.....	6-47
Table 7.2-1 - Isotopes Contributing to Atmospheric Release Doses.....	7-8
Table 7.2-2 - Atmospheric Dispersion Factors (Normal and Off-Normal Conditions).....	7-9
Table 7.2-3 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Fuel Case – Normal Conditions).....	7-10
Table 7.2-4 - Atmospheric Release Dose vs. Distance (mrem) (Typical Fuel Case – Normal Conditions).....	7-11
Table 7.2-5 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Fuel Case – Off-Normal Conditions).....	7-12
Table 7.2-6 - Atmospheric Release Dose vs. Distance (mrem) (Typical Fuel Case – Off-Normal Conditions).....	7-13
Table 7.3-1 - Atmospheric Dispersion Factors (Accident Conditions).....	7-14
Table 7.3-2 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Fuel Case – Accident Conditions).....	7-15
Table 7.3-3 - Atmospheric Release Dose vs. Distance (mrem) (Typical Fuel Case – Accident Conditions).....	7-16
Table 8.1-1 - Operations Time and Motion Summary.....	8-6
Table 10.3-1 - Personnel Requirements.....	10-8
Table 10.3-2 - Bounding Dose Rates.....	10-8
Table 10.3-3 - Expected Dose Rates.....	10-9
Table 10.3-4 - Estimated Bounding Personnel Exposure Doses.....	10-10

LIST OF TABLES

(continued)

Table 10.3-5 - Estimated Typical Personnel Exposure Doses.....	10-11
Table 10.4-1 - VSC-24 5x5 ISFSI Total Annual Doses (mrem) (Direct Radiation).....	10-12
Table 10.4-2 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Case).....	10-13
Table 10.4-3 - Atmospheric Release Dose vs. Distance (mrem) (Typical Case)	10-13
Table 10.4-4 - VSC-24 5x5 ISFSI Overall Annual Doses (mrem) (Direct Radiation + Atmospheric Release).....	10-14
Table 10.4-5 - Estimated Minimum Controlled Area Boundary Distances for a 5x5 VSC-24 Cask Array (ISFSI).....	10-15
Table 11.0-1 - Design Basis Off-Normal and Accident Events	11-22
Table 11.1-1 - MSB Stresses Resulting From Off-Normal Handling Event.....	11-23
Table 11.1-2 - MSB Stresses Resulting from Off-Normal Pressure Event.....	11-24
Table 11.2-1 - Summary of MSB Stresses Resulting from the Horizontal Drop	11-25
Table 11.2-2 - Summary of MSB Stresses Resulting from the Vertical Drop	11-26
Table 11.2-3 - Summary of MSB Stresses Resulting from Hypothetical Accident Pressurization.....	11-27
Table D.1-1 - Summary of Wide and Narrow Area Thermal Analysis	D-4

LIST OF FIGURES

Figure 1.1-1 - VSC-24 System Components	1-19
Figure 1.1-2 - VSC-24 Operations Using MTC	1-20
Figure 1.4-1 - Typical ISFSI Pad Layout	1-21
Figure 3.2-1 - VSC-24 System Weights and Centers of Gravity.....	3-30
Figure 3.4-1 - Finite Element Model for the MSB Lift Analysis	3-31
Figure 3.4-2 - Finite Element Model of MTC Wall Near Trunnion.....	3-32
Figure 3.4-3 - MSB Storage Sleeve Assembly Finite Element Model for Thermal Stress Evaluation.....	3-33
Figure 3.4-4 - MSB Body Finite Element Model for Thermal Stress Evaluation.....	3-34
Figure 3.4-5 - VCC Finite Element Model for Thermal Stress Evaluation.....	3-35
Figure 3.4-6 - Summary of VCC Thermal Stress 75°F Ambient Air, Normal Operation	3-36
Figure 3.4-7 - Finite Element Model MSB Dead Weight Analysis MSB Supported on Ceramic Tiles.....	3-37
Figure 4.1-1 - Effects of Ambient Conditions on Cask Temperatures	4-19
Figure 4.4-1 - Axial Heat Source Distribution	4-20
Figure 4.4-2 - VCC Thermal Model	4-21
Figure 4.4-3 - MSB Thermal Analysis Model.....	4-22
Figure 4.4-4 - MTC Through Wall Temperature Distribution	4-23
Figure 4.4-5 - VCC Temperature Distribution 75°F Day	4-24
Figure 4.4-6 - MSB Temperature Distribution	4-25
Figure 4.4-7 - Component Temperatures Versus Time	4-26
Figure 5.1-1 - Storage Cask Calculated Dose Rate Locations.....	5-35
Figure 5.1-2 - Transfer Cask Calculated Dose Rate Locations	5-36
Figure 5.3-1 - VSC-24 Storage Cask Bulk Shielding Model Geometry	5-37
Figure 5.3-2 - MSB Interior Shielding Model Geometry (view of horizontal cross section).....	5-38
Figure 5.3-3 - VSC-24 Storage Cask Outlet Duct Geometry (view of vertical cross section).....	5-39

LIST OF FIGURES

(continued)

Figure 5.3-4 - VSC-24 Storage Cask Inlet Duct Geometry (view of vertical cross section).....	5-40
Figure 5.3-5 - VSC-24 Storage Cask Inlet Duct Geometry (view of horizontal cross section).....	5-41
Figure 5.3-6 - VSC-24 Transfer Cask Shielding Model Geometry (view of vertical cross section).....	5-42
Figure 5.5-1 - Shielding Model for VCC Side Dose Rate Calculations for Assembly Fuel Zone Cobalt in the Inner 12 MSB Locations.....	5-43
Figure 6.1-1 - Full Symmetry Horizontal Cross-Sectional View of MSB Inside MTC	6-48
Figure 6.2-1 - B&W 15x15 Assembly Class Lattice Layout.....	6-49
Figure 6.2-2 - W 14x14 Assembly Class Lattice Layout	6-50
Figure 6.2-3 - W 15x15 Assembly Class Lattice Layout	6-51
Figure 6.2-4 - W 17x17 Assembly Class Lattice Layout	6-52
Figure 6.2-5 - CE 15x15A Assembly Class Lattice Layout	6-53
Figure 6.2-6 - CE 15x15B Assembly Class Lattice Layout	6-54
Figure 6.2-7 - CE 15x15C Assembly Class Lattice Layout	6-55
Figure 6.2-8 - CE 16x16 Assembly Class Lattice Layout	6-56
Figure 6.3-1 - 1/8 th Symmetry Horizontal Cross-Sectional View of MCNP4A Model	6-57
Figure 6.3-2 - Fuel Assembly Shifting Patterns	6-58
Figure 6.3-3 - Full Symmetry Horizontal Cross-Sectional View of MSB Shifted Inside MTC.....	6-59
Figure 6.4-1 - B&W 15x15 Assembly Class Minimum Required Soluble Boron Results.....	6-60
Figure 6.4-2 - W 14x14 Assembly Class Minimum Required Soluble Boron Results	6-61
Figure 6.4-3 - W 15x15 Assembly Class Minimum Required Soluble Boron Results	6-62
Figure 6.4-4 - W 17x17 Assembly Class Minimum Required Soluble Boron Results	6-63
Figure 6.4-5 - CE 15x15A Assembly Class Minimum Required Soluble Boron Results	6-64
Figure 6.4-6 - CE 15x15B Assembly Class Minimum Required Soluble Boron Results	6-65
Figure 6.4-7 - CE 15x15C Assembly Class Minimum Required Soluble Boron Results	6-66

LIST OF FIGURES

(continued)

Figure 6.4-8 - CE 16x16 Assembly Class Minimum Required Soluble Boron Results	6-67
Figure 8.0-1 - Flow Diagram of VSC System Handling Procedures.....	8-7
Figure 8.2-1 - Flowchart for One Typical Method of Recovering Fuel From the VSC	8-8
Figure 11.1-1 - VSC Temperature Distribution for 100°F Ambient Conditions	11-29
Figure 11.1-2 - VSC Temperature Distribution for -40°F Ambient Conditions.....	11-30
Figure 11.2-1 - MSB Storage Sleeve Model.....	11-31
Figure 11.2-2 - MSB Body Finite Element Model for Horizontal Drop Analysis	11-32
Figure 11.2-3 - Sketch of Missile Cask Impact Geometry	11-33
Figure 11.2-4 - Cask Tip-Over Requirements	11-34
Figure 11.2-5 - Outlet Air Temperature.....	11-35
Figure B.3-1 - VSC Lifting Arrangement.....	B-4
Figure B.3-2 - VSC Lifting Arm.....	B-5
Figure C.2-1 - Comparison of IDS Cladding Temperature Limit Curves For Spent Fuel Of Varying Ages.....	C-3

LIST OF EFFECTIVE PAGES

Page	Active Revision
i	7
ii	7
iii	7
iv	7
v	7
vi	7
vii	7
viii	7
ix	7
x	7
xi	7
xii	7
xiii	7
xiv	7
xv	7
xvi	7
xvii	7
xviii	7
xix	7
xx	7
xxi	7
xxii	7
1-1	6
1-2	6
1-3	6
1-4	6
1-5	6
1-6	6
1-7	6
1-8	7
1-9	6
1-10	6
1-11	6
1-12	6
1-13	6
1-14	6
1-15	6
1-16	6
1-17	6
1-18	6
1-19	6
1-20	6
1-21	6
1-22	6

Page	Active Revision
1-23	6
VCC-24-001, Sht. 1/2	6
VCC-24-001, Sht. 2/2	4
VCC-24-002, Sht. 1/3	5
VCC-24-002, Sht. 2/3	5
VCC-24-002, Sht. 3/3	3
VCC-24-003, Sht. 1/1	2
VCC-24-004, Sht. 1/1	2
VCC-24-005, Sht. 1/1	2
VCC-24-006, Sht. 1/2	5
VCC-24-006, Sht. 2/2	3
VCC-24-008, Sht. 1/1	3
MSB-24-001, Sht. 1/2	6
MSB-24-001, Sht. 2/2	5
MSB-24-002, Sht. 1/2	6
MSB-24-002, Sht. 2/2	4
MSB-24-003, Sht. 1/1	6
MSB-24-004, Sht. 1/3	6
MSB-24-004, Sht. 2/3	1
MSB-24-004, Sht. 3/3	4
MTC-24-001, Sht. 1/2	5
MTC-24-001, Sht. 2/2	5
MTC-24-002, Sht. 1/2	5

Page	Active Revision
MTC-24-002, Sht. 2/2	5
MTC-24-003, Sht. 1/2	3
MTC-24-003, Sht. 2/2	3
MTC-24-005, Sht. 1/1	4
MTC-24-006, Sht. 1/1	2
MTC-24-007, Sht. 1/1	5
MTC-24-008, Sht. 1/1	5
MTC-24-009, Sht. 1/2	3
MTC-24-009, Sht. 2/2	0
MTC-24-010, Sht. 1/2	2
MTC-24-010, Sht. 2/2	2
2-1	6
2-2	6
2-3	6
2-4	6
2-5	6
2-6	6
2-7	6
2-8	6
2-9	6
2-10	6
2-11	6
2-12	6
2-13	6
2-14	6
2-15	6
2-16	6
2-17	6
2-18	6
2-19	6
2-20	6
2-21	6
2-22	6
2-23	6

LIST OF EFFECTIVE PAGES

Page	Active Revision
2-24	6
2-25	6
3-1	6
3-2	6
3-3	6
3-4	6
3-5	6
3-6	6
3-7	6
3-8	6
3-9	6
3-10	6
3-11	6
3-12	6
3-13	6
3-14	6
3-15	6
3-16	6
3-17	6
3-18	6
3-19	6
3-20	6
3-21	6
3-22	6
3-23	6
3-24	6
3-25	6
3-26	6
3-27	6
3-28	6
3-29	6
3-30	6
3-31	6
3-32	6
3-33	6
3-34	6
3-35	6
3-36	6
4-1	6
4-2	6
4-3	6
4-4	6
4-5	6
4-6	6

Page	Active Revision
4-7	6
4-8	6
4-9	6
4-10	6
4-11	6
4-12	6
4-13	6
4-14	6
4-15	6
4-16	6
4-17	6
4-18	6
4-19	6
4-20	6
4-21	6
4-22	6
4-23	6
4-24	6
4-25	6
4-26	6
5-1	6
5-2	6
5-3	6
5-4	6
5-5	6
5-6	6
5-7	6
5-8	6
5-9	6
5-10	6
5-11	6
5-12	6
5-13	6
5-14	6
5-15	6
5-16	6
5-17	6
5-18	6
5-19	6
5-20	6
5-21	6
5-22	6
5-23	6
5-24	6

Page	Active Revision
5-25	6
5-26	6
5-27	6
5-28	6
5-29	6
5-30	6
5-31	6
5-32	6
5-33	6
5-34	6
5-35	6
5-36	6
5-37	6
5-38	6
5-39	6
5-40	6
5-41	6
5-42	6
6-1	6
6-2	6
6-3	6
6-4	6
6-5	6
6-6	6
6-7	6
6-8	6
6-9	6
6-10	6
6-11	6
6-12	6
6-13	6
6-14	6
6-15	6
6-16	6
6-17	6
6-18	6
6-19	6
6-20	6
6-21	6
6-22	6
6-23	6
6-24	6
6-25	6
6-26	6

LIST OF EFFECTIVE PAGES

Page	Active Revision
6-27	6
6-28	6
6-29	6
6-30	6
6-31	6
6-32	6
6-33	6
6-34	6
6-35	6
6-36	6
6-37	6
6-38	6
6-39	6
6-40	6
6-41	6
6-42	6
6-43	6
6-44	6
6-45	6
6-46	6
6-47	6
6-48	6
6-49	6
6-50	6
6-51	6
6-52	6
6-53	6
6-54	6
6-55	6
6-56	6
6-57	6
6-58	6
6-59	6
6-60	6
6-61	6
6-62	6
6-63	6
6-64	6
7-1	6
7-2	6
7-3	6
7-4	6
7-5	6
7-6	6

Page	Active Revision
7-7	6
7-8	6
7-9	6
7-10	6
7-11	6
7-12	6
7-13	6
7-14	6
7-15	6
7-16	6
8-1	6
8-2	6
8-3	6
8-4	6
8-5	6
8-6	6
8-7	6
8-8	6
9-1	6
9-2	6
9-3	6
10-1	6
10-2	6
10-3	6
10-4	6
10-5	6
10-6	6
10-7	6
10-8	6
10-9	6
10-10	6
10-11	6
10-12	6
10-13	6
10-14	6
10-15	6
11-1	6
11-2	6
11-3	6
11-4	6
11-5	6
11-6	6
11-7	6
11-8	6

Page	Active Revision
11-9	6
11-10	6
11-11	6
11-12	6
11-13	6
11-14	6
11-15	6
11-16	6
11-17	6
11-18	6
11-19	6
11-20	6
11-21	6
11-22	6
11-23	6
11-24	6
11-25	6
11-26	6
11-27	6
11-28	6
11-29	6
11-30	6
11-31	6
11-32	6
11-33	6
11-34	6
12-1	6
12-2	6
TOC-ii	6
TOC-iii	6
TS-1	6
TS-2	6
TS-3	6
TS-4	6
TS-5	6
TS-6	6
TS-7	6
TS-8	6
TS-9	6
TS-10	6
TS-11	6
TS-12	6
TS-13	6
TS-14	6

LIST OF EFFECTIVE PAGES

Page	Active Revision
TS-15	6
TS-16	6
TS-17	6
TS-18	6
TS-19	6
TS-20	6
TS-21	6
TS-22	6
TS-23	6
TS-24	6
TS-25	6
TS-26	6
TS-27	6
TS-28	6
TS-29	6
TS-30	6
TS-31	6
TS-32	6
TS-33	6
TS-34	6
TS-35	6
TS-36	6
TS-37	6
TS-38	6
TS-39	6
TS-40	6
TS-41	6
TS-42	6
TS-43	6
TS-44	6
TS-45	6
TS-46	6
TS-47	6
TS-48	6
TS-49	6
TS-50	6
TS-51	6
TS-52	6
TS-53	6
TS-54	6
TS-55	6
TS-56	6
TS-57	6
TS-58	6

Page	Active Revision
TS-59	6
TS-60	6
TS-61	6
TS-62	6
TS-63	6
TS-64	6
TS-65	6
TS-66	6
TS-67	6
13-1	7
14-1	6
14-2	6
14-3	6
14-4	6
14-5	6
A-1	6
A-2	6
A-3	6
A-4	6
A-5	6
B-1	6
B-2	6
B-3	6
B-4	6
B-5	6
C-1	6
C-2	6
C-3	6
D-1	6
D-2	6
D-3	6
D-4	6
F-1	6
Specification VMSB-98- 001	5

2. Load fuel assemblies in the MSB.
3. Place shielding lid on MSB and use transfer cask to remove MSB from fuel pool.
4. Close MSB. (See discussion in Chapter 8.)
5. Transfer MSB to concrete cask.
6. Close VCC.
7. Move VCC to storage location via truck trailer.
8. Position VCC at storage site via hydraulic roller skid.

Safe storage of the irradiated fuel in the VSC-24 System is provided by the removal of decay heat by convection, radiation, and conduction from the fuel rods to the MSB shell wall and the subsequent natural convection in the MSB-VCC annulus. Radiation exposure to site personnel is limited by the steel and concrete shielding. VSC-24 System operation is totally passive. No active systems are required.

The handling equipment required to implement the VSC-24 System is site-specific. This equipment includes an overhead handling crane at the reactor fuel pool, one transfer cask, one hydraulic roller skid, one yoke, and one transfer trailer. All equipment is designed and tested to applicable government and industrial standards and will be maintained and operated to the owner's specifications.

1.2.3 CASK CONTENTS

The fuel to be stored in the VSC-24 System is described in Section 2.1 of this FSAR. In addition to the fuel, the MSB will contain a helium cover gas.

1.3 IDENTIFICATION OF AGENTS AND CONTRACTORS

The owner of the design and Certificate of Compliance for the VSC-24 Ventilated Storage System is *EnergySolutions Spent Fuel Division, Inc. (EnergySolutions SFD)*. *EnergySolutions SFD* is a wholly owned subsidiary of *EnergySolutions LLC*. All design and specification activities including quality assurance services continue to be performed by *EnergySolutions SFD*. Fabrication of the steel components (MSB, MTC) will be by a qualified steel fabrication shop chosen through a competitive bidding process. Fabrication of the VCC will be performed by a local concrete contractor, also chosen by the bid process. *EnergySolutions SFD* will retain full responsibility and control over all design, analysis, and fabrication activities.

Additional agents/contractors that may build and deliver VSC-24 systems and components are Wisconsin Electric Power Company of Milwaukee, Wisconsin. Wisconsin Electric Power Company will only build the VSC-24 systems and components for their own use and will build them under their own 10 CFR 50 Appendix B QA Program. *EnergySolutions SFD* will build casks and components for other users under the Manual of Quality Assurance referenced in Chapter 13 of this FSAR.

13.0 QUALITY ASSURANCE

EnergySolutions SFD will apply its Manual of Quality Assurance as approved by the Nuclear Regulatory Commission for Subpart G of the 10CFR Part 72.

Docket 72-1007
Revision 7

**Final Safety Analysis Report
For the
VSC-24 Ventilated Storage Cask System**

Prepared by:

**EnergySolutions Spent Fuel Division, Inc.
Campbell, California**

April 2007

TABLE OF CONTENTS

1.0 GENERAL DESCRIPTION	1-1
1.1 INTRODUCTION.....	1-1
1.2 GENERAL DESCRIPTION OF THE STORAGE CASK	1-2
1.2.1 CASK SYSTEM CHARACTERISTICS.....	1-2
1.2.1.1 Description of the MSB	1-3
1.2.1.2 Description of the VCC	1-5
1.2.1.3 Description of the MTC.....	1-6
1.2.1.4 Description of the Roller Skid	1-7
1.2.1.5 Transfer Trailer	1-7
1.2.2 OPERATIONAL FEATURES.....	1-7
1.2.3 CASK CONTENTS.....	1-8
1.3 IDENTIFICATION OF AGENTS AND CONTRACTORS.....	1-8
1.4 GENERIC CASK ARRAYS.....	1-9
1.5 SUPPLEMENTAL DATA.....	1-22
2.0 PRINCIPAL DESIGN CRITERIA	2-1
2.1 IRRADIATED FUEL TO BE STORED.....	2-1
2.2 DESIGN CRITERIA FOR ENVIRONMENTAL CONDITIONS AND NATURAL PHENOMENA.....	2-2
2.2.1 ENVIRONMENTAL TEMPERATURES.....	2-2
2.2.2 TORNADO AND WIND LOADINGS	2-3
2.2.3 WATER LEVEL (FLOOD) DESIGN	2-4
2.2.4 SNOW AND ICE LOADINGS.....	2-4
2.2.5 SEISMIC DESIGN	2-4
2.2.6 COMBINED LOAD CRITERIA	2-5
2.2.6.1 Load Combinations and Design Strength - Concrete Cask.....	2-5
2.2.6.2 Load Combinations and Design Strength - MSB Steel Vessel.....	2-5
2.2.6.3 Design Strength - MSB Transfer Cask.....	2-6
2.3 SAFETY PROTECTION SYSTEMS	2-6
2.3.1 GENERAL	2-6
2.3.2 PROTECTION BY MULTIPLE CONFINEMENT BARRIERS AND SYSTEMS.....	2-7

TABLE OF CONTENTS

(continued)

2.3.2.1	Confinement Barriers and Systems	2-7
2.3.2.2	Ventilation Off-Gas.....	2-8
2.3.3	PROTECTION BY EQUIPMENT AND INSTRUMENTATION SELECTION	2-8
2.3.3.1	Equipment	2-8
2.3.3.2	Instrumentation	2-8
2.3.4	NUCLEAR CRITICALITY SAFETY	2-9
2.3.5	RADIOLOGICAL PROTECTION.....	2-9
2.3.5.1	Access Control	2-9
2.3.5.2	Shielding.....	2-9
2.3.5.3	Radiological Alarm Systems	2-10
2.3.6	FIRE AND EXPLOSION PROTECTION	2-10
2.3.7	LIGHTNING.....	2-10
2.4	DECOMMISSIONING CONSIDERATIONS.....	2-10
3.0	STRUCTURAL EVALUATION	3-1
3.1	STRUCTURAL DESIGN.....	3-1
3.1.1	DISCUSSION	3-1
3.1.2	DESIGN CRITERIA	3-2
3.2	WEIGHTS AND CENTERS OF GRAVITY	3-2
3.3	MECHANICAL PROPERTIES OF MATERIALS.....	3-2
3.4	GENERAL STANDARDS FOR CASKS.....	3-3
3.4.1	CHEMICAL AND GALVANIC REACTIONS.....	3-3
3.4.2	POSITIVE CLOSURE	3-3
3.4.3	LIFTING DEVICES	3-3
3.4.3.1	VSC Bottom Lift.....	3-4
3.4.3.2	MSB Lift	3-4
3.4.3.3	MTC Lift.....	3-5
3.4.4	VSC COMPONENTS UNDER NORMAL OPERATING LOADS.....	3-7
3.4.4.1	MSB Analysis	3-7
3.4.4.1.1	MSB Thermal Stress Analysis.....	3-8
3.4.4.1.2	Dead Weight Load Analysis.....	3-9
3.4.4.1.3	MSB Internal Pressure Analysis.....	3-12

TABLE OF CONTENTS

(continued)

3.4.4.1.4	MSB Handling Stresses	3-13
3.4.4.1.5	MSB Load Combination.....	3-14
3.4.4.1.6	MSB Pressure Test	3-15
3.4.4.2	VCC Analysis.....	3-15
3.4.4.2.1	VCC Dead Load	3-16
3.4.4.2.2	VCC Live Load.....	3-16
3.4.4.2.3	VCC Thermal Stresses.....	3-16
3.4.4.3	MTC Stress Calculations and Comparison with Allowables.....	3-18
3.4.5	COLD.....	3-18
3.4.5.1	MSB	3-18
3.4.5.2	MTC	3-19
3.5	FUEL RODS.....	3-19
4.0	THERMAL EVALUATION	4-1
4.1	DISCUSSION.....	4-1
4.2	SUMMARY OF THERMAL PROPERTIES OF MATERIALS.....	4-2
4.3	TECHNICAL SPECIFICATION OF COMPONENTS	4-2
4.4	THERMAL EVALUATION FOR NORMAL STORAGE CONDITIONS.....	4-3
4.4.1	THERMAL MODELS.....	4-3
4.4.1.1	Air Flow and Temperature Calculation	4-3
4.4.1.2	VCC Body and MSB Exterior Thermal Model.....	4-5
4.4.1.2.1	Heat Transfer Modes	4-5
4.4.1.2.2	VCC Thermal Hydraulic Model	4-6
4.4.1.2.3	Radiation.....	4-6
4.4.1.2.4	VCC Convections	4-6
4.4.1.2.5	VCC Modeling Assumptions.....	4-7
4.4.1.3	MSB Thermal-Hydraulics.....	4-7
4.4.1.3.1	MSB Heat Transfer Modes	4-7
4.4.1.3.2	MSB Thermal Hydraulic Model.....	4-8
4.4.1.3.3	MSB Fuel Heat Source Strength.....	4-8
4.4.1.3.4	MSB Heat Transfer Properties.....	4-8
4.4.1.3.5	MSB Model Assumptions.....	4-9
4.4.1.4	Transfer Cask Model.....	4-9

TABLE OF CONTENTS

(continued)

4.4.1.4.1	MTC Heat Transfer Modes.....	4-9
4.4.1.4.2	MTC Thermal Hydraulic Model.....	4-10
4.4.1.4.3	MSB Vacuum Cover Gas Thermal Hydraulic Model.....	4-11
4.4.1.5	Determination of VCC Surface Heat Transfer Coefficient.....	4-11
4.4.1.6	Determination of Fuel Effective Thermal Conductivities.....	4-12
4.4.2	TEST MODEL.....	4-13
4.4.3	MAXIMUM TEMPERATURES.....	4-13
4.4.4	MINIMUM TEMPERATURES.....	4-13
4.4.5	MAXIMUM INTERNAL PRESSURE.....	4-13
4.4.6	MAXIMUM THERMAL STRESSES.....	4-14
4.4.7	EVALUATION OF CASK PERFORMANCE FOR NORMAL CONDITIONS OF STORAGE.....	4-14
5.0	SHIELDING EVALUATION.....	5-1
5.1	DISCUSSION AND RESULTS.....	5-1
5.2	SOURCE SPECIFICATION.....	5-2
5.2.1	GAMMA SOURCE DESCRIPTION.....	5-3
5.2.1.1	Fuel Gamma Source.....	5-3
5.2.1.2	Assembly Hardware Gamma Sources.....	5-4
5.2.1.3	Axial Gamma Source Strength Profile.....	5-7
5.2.2	NEUTRON SOURCE DESCRIPTION.....	5-8
5.2.2.1	Total Neutron Source Strength.....	5-8
5.2.2.2	Axial Neutron Source Strength Profile.....	5-9
5.3	MODEL SPECIFICATION.....	5-11
5.3.1	STORAGE CASK MODEL GEOMETRY.....	5-11
5.3.1.1	Storage Cask Bulk Model Geometry.....	5-11
5.3.1.2	MSB Interior Model Geometry.....	5-11
5.3.1.2.1	Primary Shielding Analysis Model.....	5-11
5.3.1.2.2	Supplementary Gamma Analysis Model.....	5-12
5.3.1.3	Inlet and Outlet Duct Model Geometry.....	5-12
5.3.2	TRANSFER CASK MODEL GEOMETRY.....	5-13
5.3.3	SHIELD REGIONAL DENSITIES.....	5-14

TABLE OF CONTENTS

(continued)

5.4	SHIELDING EVALUATION	5-15
5.4.1	SHIELDING ANALYSIS CODE	5-15
5.4.2	MCNP AREA DETECTORS.....	5-15
5.4.3	FLUX-TO-DOSE CONVERSION FACTORS.....	5-16
5.4.4	SUPPLEMENTARY SHIELDING ANALYSES.....	5-16
5.5	SUPPLEMENTARY ANALYSES	5-17
5.5.1	ALTERNATIVE FUEL PARAMETER EVALUATION	5-17
5.5.2	EVALUATION OF ASSEMBLIES WITH HIGH HARDWARE COBALT QUANTITIES.....	5-20
6.0	CRITICALITY EVALUATION.....	6-1
6.1	Criticality Design Criteria and Features.....	6-1
6.2	Fuel Specification	6-2
6.3	Model Specification.....	6-4
6.3.1	Configuration	6-4
6.3.2	Material Properties.....	6-7
6.4	Criticality Analysis.....	6-8
6.4.1	Computer Programs	6-8
6.4.2	Multiplication Factor.....	6-9
6.4.2.1	Part 1 of Methodology: Base Case Identification	6-10
6.4.2.2	Part 2 of Methodology: Sensitivity Analysis	6-11
6.4.2.3	Part 3 of Methodology: Partial Flooding Analysis.....	6-12
6.4.2.4	Results	6-13
6.4.2.5	Compliance with Requirements.....	6-17
6.4.2.6	Range of Validity	6-17
6.4.2.7	Summary of Conservatism.....	6-17
6.4.2.8	Limitations or Special Requirements.....	6-18
6.4.3	Benchmark Comparisons.....	6-19
6.4.3.1	Methodology of Maximum Allowable K_{eff} Calculation (USL method).....	6-20
6.4.3.2	VSC-24 USL Calculations.....	6-23
7.0	CONFINEMENT.....	7-1
7.1	CONFINEMENT BOUNDARY	7-1

TABLE OF CONTENTS

(continued)

7.1.1	CONFINEMENT VESSEL.....	7-1
7.1.2	CONFINEMENT (MSB) PENETRATIONS.....	7-1
7.1.3	SEALS AND WELDS.....	7-2
7.1.3.1	Fabrication.....	7-2
7.1.3.2	Welding Specifications.....	7-3
7.1.3.3	Testing, Inspection, and Examination.....	7-3
7.1.4	CLOSURE.....	7-3
7.1.5	CONFINEMENT BOUNDARY MONITORING.....	7-3
7.2	REQUIREMENTS FOR NORMAL AND OFF-NORMAL CONDITIONS OF STORAGE.....	7-4
7.2.1	RELEASE OF RADIOACTIVE MATERIAL.....	7-4
7.2.2	PRESSURIZATION OF CONFINEMENT VESSEL.....	7-6
7.3	CONFINEMENT REQUIREMENTS FOR HYPOTHETICAL ACCIDENT CONDITIONS.....	7-7
7.3.1	FISSION GAS PRODUCTS.....	7-7
7.3.2	RELEASE OF CONTENTS.....	7-7
8.0	OPERATING PROCEDURES.....	8-1
8.1	PROCEDURES FOR LOADING THE CASK.....	8-1
8.2	PROCEDURES FOR UNLOADING THE CASK.....	8-3
8.3	PREPARATION OF THE CASK FOR ON-SITE TRANSPORT.....	8-3
8.4	SUPPLEMENTAL DATA.....	8-4
9.0	ACCEPTANCE TEST AND MAINTENANCE PROGRAM.....	9-1
9.1	ACCEPTANCE TEST.....	9-1
9.1.1	VISUAL INSPECTION.....	9-1
9.1.1.1	Fabrication Inspections.....	9-1
9.1.1.2	Inspection Prior to Use.....	9-2
9.1.2	STRUCTURAL AND PRESSURE TEST.....	9-2
9.1.3	TEST OF THE FIRST VSC PLACED IN SERVICE.....	9-3
9.2	MAINTENANCE PROGRAM.....	9-3
10.0	RADIATION PROTECTION.....	10-1

TABLE OF CONTENTS

(continued)

10.1 ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES ARE AS LOW AS IS REASONABLY ACHIEVABLE (ALARA).....	10-1
10.1.1 POLICY CONSIDERATIONS.....	10-1
10.1.2 DESIGN CONSIDERATIONS.....	10-1
10.1.3 OPERATIONAL CONSIDERATIONS.....	10-1
10.2 RADIATION PROTECTION DESIGN FEATURES.....	10-2
10.2.1 DESIGN BASIS FOR NORMAL CONDITIONS.....	10-2
10.2.2 DESIGN BASIS FOR ACCIDENT CONDITIONS.....	10-2
10.3 ESTIMATED ON-SITE COLLECTIVE DOSE ASSESSMENT.....	10-2
10.3.1 ESTIMATED OCCUPANCY REQUIREMENTS.....	10-2
10.3.2 DOSE RATES.....	10-2
10.3.3 ESTIMATED MAN-REM EXPOSURES FOR OPERATION, MAINTENANCE, AND INSPECTION OF THE EQUIPMENT.....	10-3
10.4 ESTIMATED OFF-SITE COLLECTIVE DOSE ASSESSMENT.....	10-4
10.4.1 OFF-SITE DOSE FOR NORMAL AND OFF-NORMAL OPERATIONS.....	10-5
10.4.2 OFF-SITE DOSE FOR ACCIDENT CONDITIONS.....	10-6
11.0 ACCIDENT ANALYSIS.....	11-1
11.1 OFF-NORMAL EVENTS.....	11-1
11.1.1 OFF-NORMAL, SEVERE ENVIRONMENTAL CONDITIONS.....	11-1
11.1.1.1 Cause of Event.....	11-1
11.1.1.2 Detection.....	11-2
11.1.1.3 Analysis.....	11-2
11.1.1.4 Corrective Actions.....	11-3
11.1.2 BLOCKAGE OF ONE-HALF OF THE AIR INLETS.....	11-3
11.1.2.1 Cause.....	11-3
11.1.2.2 Detection.....	11-3
11.1.2.3 Analysis, Effects, and Consequences.....	11-3
11.1.2.4 Corrective Actions.....	11-4
11.1.3 INTERFERENCE DURING MSB LOWERING FROM TRANSFER CASK INTO CONCRETE CASK.....	11-4
11.1.3.1 Cause of Event.....	11-4

TABLE OF CONTENTS

(continued)

11.1.3.2	Detection	11-4
11.1.3.3	Analysis of Effects and Consequences	11-4
11.1.3.4	Corrective Actions	11-5
11.1.4	SMALL RELEASE OF RADIOACTIVE PARTICULATES FROM THE MSB EXTERIOR	11-5
11.1.4.1	Cause of Event	11-5
11.1.4.2	Detection	11-5
11.1.4.3	Analysis of Effects and Consequences	11-6
11.1.4.4	Corrective Actions	11-6
11.1.5	MSB OFF-NORMAL HANDLING LOAD	11-6
11.1.5.1	Cause of Event	11-6
11.1.5.2	Detection	11-7
11.1.5.3	Analysis	11-7
11.1.6	OFF-NORMAL PRESSURIZATION	11-8
11.1.6.1	Cause of Pressurization	11-8
11.1.6.2	Analysis of Off-Normal Pressurization	11-8
11.1.6.3	Radiological Consequences	11-9
11.2	ACCIDENTS	11-9
11.2.1	MAXIMUM ANTICIPATED HEAT LOAD	11-9
11.2.1.1	Cause of Accident	11-9
11.2.1.2	Accident Analysis	11-9
11.2.1.3	Accident Dose Calculation	11-10
11.2.2	MSB DROP ACCIDENT	11-10
11.2.2.1	Cause of Accident	11-10
11.2.2.2	Accident Analysis	11-10
11.2.2.3	Accident Dose Calculation	11-12
11.2.3	TORNADO	11-12
11.2.3.1	Cause of a Tornado	11-12
11.2.3.2	Tornado Accident Analysis	11-12
11.2.3.3	Tornado Accident Dose Calculations	11-15
11.2.4	FLOOD	11-16
11.2.4.1	Causes of Flood	11-16
11.2.4.2	Flood Analysis	11-16

TABLE OF CONTENTS

(continued)

11.2.4.3 Flood Dose Calculations	11-17
11.2.5 EARTHQUAKE EVENT.....	11-17
11.2.5.1 Cause of Earthquake	11-17
11.2.5.2 Earthquake Analysis	11-17
11.2.5.3 Accident Dose Calculation	11-18
11.2.6 ACCIDENT PRESSURIZATION	11-18
11.2.6.1 Cause of Pressurization.....	11-18
11.2.6.2 Analysis of Pressurization Accident.....	11-19
11.2.6.3 Radiological Consequences	11-20
11.2.7 FULL BLOCKAGE OF AIR INLETS	11-20
11.2.7.1 Cause	11-20
11.2.7.2 Detection	11-20
11.2.7.3 Analysis of Event.....	11-20
11.2.7.4 Consequences of Event.....	11-21
12.0 OPERATING CONTROLS AND LIMITS	12-1
12.1 PROPOSED OPERATING CONTROLS AND LIMITS.....	12-1
12.2 DESIGN FEATURES	12-1
12.3 ADMINISTRATIVE CONTROLS	12-2
12.4 CONDITIONS FOR CASK USE AND TECHNICAL SPECIFICATIONS.....	12-2
13.0 QUALITY ASSURANCE.....	13-1
14.0 REFERENCES.....	14-1
14.1 Section References.....	14-1
14.2 Other References.....	14-4
A APPENDIX A - FUEL ASSEMBLY REGION EFFECTIVE THERMAL CONDUCTIVITY	A-1
A.1 INTRODUCTION.....	A-1
A.2 DESIGN INPUT AND ASSUMPTIONS.....	A-1
A.2.1 ASSUMPTIONS.....	A-1
A.2.2 INPUT	A-1
A.3 CALCULATIONS	A-1

TABLE OF CONTENTS

(continued)

A.3.1	APPLICATION OF THE WOOTEN-EPSTEIN CORRELATION.....	A-1
A.3.2	EXAMINATION OF CASK TEST DATA AND PRE AND POST TEST ANALYSIS USING HYDRA AND COBRA.....	A-3
A.3.3	MODEL TN-24 TEST.....	A-4
A.4	CONCLUSIONS.....	A-5
B	APPENDIX B - OPTIONAL CASK TRANSPORTER AND VSC LIFTING LUGSB-1	
B.1	INTRODUCTION.....	B-1
B.2	TRANSPORTER.....	B-1
B.3	VSC LIFTING LUGS.....	B-1
C	APPENDIX C - FUEL INERT DRY STORAGE TEMPERATURE LIMITS.....	C-1
C.1	INTRODUCTION.....	C-1
C.2	ANALYSIS.....	C-1
C.3	RESULTS AND CONCLUSIONS.....	C-2
D	APPENDIX D - EFFECTIVE THERMAL CONDUCTIVITIES FOR WIDE AND NARROW AREAS WITHIN THE MSB.....	D-1
D.1	INTRODUCTION.....	D-1
D.2	ANALYSIS.....	D-1
D.3	RESULTS AND CONCLUSIONS.....	D-2
E	APPENDIX E - NOT USED.....	E-1
F	APPENDIX F - SPECIFICATION VMSB-98-001.....	F-1

LIST OF TABLES

Table 1.2-1 - Summary of VSC-24 System Design Criteria (2 pages).....	1-10
Table 1.2-2 - Major Physical Design Characteristics for the 24 Assembly MSB	1-12
Table 1.2-3 - MSB Fabrication Summary.....	1-13
Table 1.2-4 - Major Physical Design Parameters for the 24 Assembly VCC	1-14
Table 1.2-5 - VCC Construction Summary	1-15
Table 1.2-6 - Major Physical Design Parameters for the 24 Assembly MTC.....	1-16
Table 1.2-7 - Exceptions to ASME Section III Requirements for the MSB (2 pages).....	1-17
Table 2.0-1 - VCC Design Parameters (2 pages).....	2-12
Table 2.0-2 - MSB Design Parameters (2 pages)	2-14
Table 2.0-3 - MTC Design Parameters (2 pages)	2-16
Table 2.0-4 - Design Configurations for Calculations (2 pages).....	2-18
Table 2.1-1 - Principal Design Parameters for PWR Fuel Assemblies to be Stored in a Ventilated Storage Cask	2-20
Table 2.2-1 - Tornado-Generated Missiles	2-21
Table 2.2-2 - Load Combinations for the VSC Concrete Cask	2-22
Table 2.2-3 - MSB Load Combinations.....	2-23
Table 2.2-4 - Structural Design Criteria for Steel Components Used in the Multi-Assembly Sealed Basket	2-24
Table 2.3-1 - Radioactivity Confinement Barriers and Systems of the VSC System	2-25
Table 3.2-1 - VSC System Weights and Centers of Gravity	3-20
Table 3.3-1 - Mechanical Properties of Steels Used in the VSC.....	3-21
Table 3.4-1 - MSB-24 Design Loadings.....	3-22
Table 3.4-2 - Summary of Maximum VSC Temperatures for Structural Evaluation.....	3-23
Table 3.4-3 - Summary of Results MSB Storage Sleeve Assembly Thermal Stresses	3-24
Table 3.4-4 - Summary of Maximum MSB Body Thermal Stresses (ksi)	3-25
Table 3.4-6 - VCC Structural Load Combination Evaluation	3-28
Table 3.4-7 - Summary of Maximum VCC Thermal Stresses 75°F Ambient Air, Normal Operation	3-29

LIST OF TABLES

(continued)

Table 4.1-1 - Summary of VSC System Thermal Hydraulics Evaluation.....	4-15
Table 4.2-1 - Thermal Properties.....	4-16
Table 4.3-1 - Condition Categories and Temperature Limits for Concrete.....	4-17
Table 4.4-1 - Summary of VSC Cooling Air Flow Analysis.....	4-18
Table 5.1-1 - Storage Cask Exterior Dose Rates	5-24
Table 5.1-2 - Transfer Cask Exterior Dose Rates.....	5-25
Table 5.2-1 - Assembly Fuel Zone Gamma Source Strengths.....	5-26
Table 5.2-2 - Assembly Hardware Source Strength Calculation.....	5-27
Table 5.2-3 - Assembly Non-Fuel Zone Hardware Gamma Source Strengths.....	5-28
Table 5.2-4 - Gamma and Neutron Axial Source Strength Profiles	5-29
Table 5.3-1 - VSC-24 Cask Material Elemental Compositions.....	5-30
Table 5.3-2 - MSB Interior Homogenized Material Elemental Densities	5-31
Table 5.4-1 - Gamma Flux-to-Dose Conversion Factors (ANSI/ANS-6.1.1-1977).....	5-32
Table 5.4-2 - Neutron Flux-to-Dose Conversion Factors (ANSI/ANS-6.1.1-1977)	5-33
Table 5.5-1 - VSC-24 Minimum Required Assembly Cooling Time vs. Burnup and Enrichment.....	5-34
Table 6.1-1 - MSB and MTC Component Dimensions (Actual and Modeled).....	6-25
Table 6.2-1(a) - Fuel Assembly Class Characterization Parameters	6-26
Table 6.2-1(b) - Fuel Assembly Class Characterization Parameters	6-27
Table 6.3-1 - MSB and MTC Material Compositions	6-28
Table 6.3-2 - UO ₂ Fuel Compositions	6-29
Table 6.4-1 - Criticality Analysis Results for the B&W 15x15 Assembly Class ^[1,2]	6-30
Table 6.4-2 - Criticality Analysis Results for the W 14x14 Assembly Class ^[1,2]	6-31
Table 6.4-3 - Criticality Analysis Results for the W 15x15 Assembly Class ^[1]	6-32
Table 6.4-4 - Criticality Analysis Results for the W 17x17 Assembly Class ^[1,2]	6-33
Table 6.4-5 - Criticality Analysis Results for the CE 15x15A Assembly Class ^[1]	6-35

LIST OF TABLES

(continued)

Table 6.4-6 - Criticality Analysis Results for the CE 15x15B Assembly Class ^[1,2]	6-36
Table 6.4-7 - Criticality Analysis Results for the CE 15x15C Assembly Class ^[1,2]	6-38
Table 6.4-8 - Criticality Analysis Results for the CE 16x16 Assembly Class ^[1]	6-40
Table 6.4-9 - Results of Criticality Sensitivity Analyses (Δk_{eff}) ¹	6-41
Table 6.4-10 - Characteristic Parameters of VSC-24 Critical Benchmarks (2 pages)	6-42
Table 6.4-11 - USL Equation Parameter Values	6-44
Table 6.4-12 - USL Functions Applicable to the VSC-24 System (2 pages)	6-45
Table 6.4-13 - Range of Physical Parameter Values for VSC-24 Criticality Evaluations	6-47
Table 7.2-1 - Isotopes Contributing to Atmospheric Release Doses	7-8
Table 7.2-2 - Atmospheric Dispersion Factors (Normal and Off-Normal Conditions)	7-9
Table 7.2-3 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Fuel Case – Normal Conditions)	7-10
Table 7.2-4 - Atmospheric Release Dose vs. Distance (mrem) (Typical Fuel Case – Normal Conditions)	7-11
Table 7.2-5 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Fuel Case – Off-Normal Conditions)	7-12
Table 7.2-6 - Atmospheric Release Dose vs. Distance (mrem) (Typical Fuel Case – Off-Normal Conditions)	7-13
Table 7.3-1 - Atmospheric Dispersion Factors (Accident Conditions)	7-14
Table 7.3-2 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Fuel Case – Accident Conditions)	7-15
Table 7.3-3 - Atmospheric Release Dose vs. Distance (mrem) (Typical Fuel Case – Accident Conditions)	7-16
Table 8.1-1 - Operations Time and Motion Summary	8-6
Table 10.3-1 - Personnel Requirements	10-8
Table 10.3-2 - Bounding Dose Rates	10-8
Table 10.3-3 - Expected Dose Rates	10-9
Table 10.3-4 - Estimated Bounding Personnel Exposure Doses	10-10

LIST OF TABLES

(continued)

Table 10.3-5 - Estimated Typical Personnel Exposure Doses.....	10-11
Table 10.4-1 - VSC-24 5x5 ISFSI Total Annual Doses (mrem) (Direct Radiation).....	10-12
Table 10.4-2 - Atmospheric Release Dose vs. Distance (mrem) (Bounding Case).....	10-13
Table 10.4-3 - Atmospheric Release Dose vs. Distance (mrem) (Typical Case).....	10-13
Table 10.4-4 - VSC-24 5x5 ISFSI Overall Annual Doses (mrem) (Direct Radiation + Atmospheric Release).....	10-14
Table 10.4-5 - Estimated Minimum Controlled Area Boundary Distances for a 5x5 VSC-24 Cask Array (ISFSI).....	10-15
Table 11.0-1 - Design Basis Off-Normal and Accident Events	11-22
Table 11.1-1 - MSB Stresses Resulting From Off-Normal Handling Event.....	11-23
Table 11.1-2 - MSB Stresses Resulting from Off-Normal Pressure Event.....	11-24
Table 11.2-1 - Summary of MSB Stresses Resulting from the Horizontal Drop	11-25
Table 11.2-2 - Summary of MSB Stresses Resulting from the Vertical Drop	11-26
Table 11.2-3 - Summary of MSB Stresses Resulting from Hypothetical Accident Pressurization.....	11-27
Table D.1-1 - Summary of Wide and Narrow Area Thermal Analysis.....	D-4

LIST OF FIGURES

Figure 1.1-1 - VSC-24 System Components	1-19
Figure 1.1-2 - VSC-24 Operations Using MTC	1-20
Figure 1.4-1 - Typical ISFSI Pad Layout	1-21
Figure 3.2-1 - VSC-24 System Weights and Centers of Gravity.....	3-30
Figure 3.4-1 - Finite Element Model for the MSB Lift Analysis	3-31
Figure 3.4-2 - Finite Element Model of MTC Wall Near Trunnion.....	3-32
Figure 3.4-3 - MSB Storage Sleeve Assembly Finite Element Model for Thermal Stress Evaluation	3-33
Figure 3.4-4 - MSB Body Finite Element Model for Thermal Stress Evaluation	3-34
Figure 3.4-5 - VCC Finite Element Model for Thermal Stress Evaluation.....	3-35
Figure 3.4-6 - Summary of VCC Thermal Stress 75°F Ambient Air, Normal Operation	3-36
Figure 3.4-7 - Finite Element Model MSB Dead Weight Analysis MSB Supported on Ceramic Tiles.....	3-37
Figure 4.1-1 - Effects of Ambient Conditions on Cask Temperatures	4-19
Figure 4.4-1 - Axial Heat Source Distribution	4-20
Figure 4.4-2 - VCC Thermal Model	4-21
Figure 4.4-3 - MSB Thermal Analysis Model.....	4-22
Figure 4.4-4 - MTC Through Wall Temperature Distribution	4-23
Figure 4.4-5 - VCC Temperature Distribution 75°F Day	4-24
Figure 4.4-6 - MSB Temperature Distribution	4-25
Figure 4.4-7 - Component Temperatures Versus Time	4-26
Figure 5.1-1 - Storage Cask Calculated Dose Rate Locations.....	5-35
Figure 5.1-2 - Transfer Cask Calculated Dose Rate Locations	5-36
Figure 5.3-1 - VSC-24 Storage Cask Bulk Shielding Model Geometry	5-37
Figure 5.3-2 - MSB Interior Shielding Model Geometry (view of horizontal cross section).....	5-38
Figure 5.3-3 - VSC-24 Storage Cask Outlet Duct Geometry (view of vertical cross section).....	5-39

LIST OF FIGURES

(continued)

Figure 5.3-4 - VSC-24 Storage Cask Inlet Duct Geometry (view of vertical cross section).....	5-40
Figure 5.3-5 - VSC-24 Storage Cask Inlet Duct Geometry (view of horizontal cross section).....	5-41
Figure 5.3-6 - VSC-24 Transfer Cask Shielding Model Geometry (view of vertical cross section).....	5-42
Figure 5.5-1 - Shielding Model for VCC Side Dose Rate Calculations for Assembly Fuel Zone Cobalt in the Inner 12 MSB Locations.....	5-43
Figure 6.1-1 - Full Symmetry Horizontal Cross-Sectional View of MSB Inside MTC.....	6-48
Figure 6.2-1 - B&W 15x15 Assembly Class Lattice Layout.....	6-49
Figure 6.2-2 - W 14x14 Assembly Class Lattice Layout	6-50
Figure 6.2-3 - W 15x15 Assembly Class Lattice Layout	6-51
Figure 6.2-4 - W 17x17 Assembly Class Lattice Layout	6-52
Figure 6.2-5 - CE 15x15A Assembly Class Lattice Layout	6-53
Figure 6.2-6 - CE 15x15B Assembly Class Lattice Layout	6-54
Figure 6.2-7 - CE 15x15C Assembly Class Lattice Layout	6-55
Figure 6.2-8 - CE 16x16 Assembly Class Lattice Layout	6-56
Figure 6.3-1 - 1/8 th Symmetry Horizontal Cross-Sectional View of MCNP4A Model	6-57
Figure 6.3-2 - Fuel Assembly Shifting Patterns	6-58
Figure 6.3-3 - Full Symmetry Horizontal Cross-Sectional View of MSB Shifted Inside MTC.....	6-59
Figure 6.4-1 - B&W 15x15 Assembly Class Minimum Required Soluble Boron Results.....	6-60
Figure 6.4-2 - W 14x14 Assembly Class Minimum Required Soluble Boron Results	6-61
Figure 6.4-3 - W 15x15 Assembly Class Minimum Required Soluble Boron Results	6-62
Figure 6.4-4 - W 17x17 Assembly Class Minimum Required Soluble Boron Results	6-63
Figure 6.4-5 - CE 15x15A Assembly Class Minimum Required Soluble Boron Results.....	6-64
Figure 6.4-6 - CE 15x15B Assembly Class Minimum Required Soluble Boron Results	6-65
Figure 6.4-7 - CE 15x15C Assembly Class Minimum Required Soluble Boron Results	6-66

LIST OF FIGURES

(continued)

Figure 6.4-8 - CE 16x16 Assembly Class Minimum Required Soluble Boron Results	6-67
Figure 8.0-1 - Flow Diagram of VSC System Handling Procedures.....	8-7
Figure 8.2-1 - Flowchart for One Typical Method of Recovering Fuel From the VSC.....	8-8
Figure 11.1-1 - VSC Temperature Distribution for 100°F Ambient Conditions	11-29
Figure 11.1-2 - VSC Temperature Distribution for -40°F Ambient Conditions.....	11-30
Figure 11.2-1 - MSB Storage Sleeve Model.....	11-31
Figure 11.2-2 - MSB Body Finite Element Model for Horizontal Drop Analysis	11-32
Figure 11.2-3 - Sketch of Missile Cask Impact Geometry	11-33
Figure 11.2-4 - Cask Tip-Over Requirements	11-34
Figure 11.2-5 - Outlet Air Temperature.....	11-35
Figure B.3-1 - VSC Lifting Arrangement.....	B-4
Figure B.3-2 - VSC Lifting Arm.....	B-5
Figure C.2-1 - Comparison of IDS Cladding Temperature Limit Curves For Spent Fuel Of Varying Ages.....	C-3

LIST OF EFFECTIVE PAGES

Page	Active Revision
i	7
ii	7
iii	7
iv	7
v	7
vi	7
vii	7
viii	7
ix	7
x	7
xi	7
xii	7
xiii	7
xiv	7
xv	7
xvi	7
xvii	7
xviii	7
xix	7
xx	7
xxi	7
xxii	7
1-1	6
1-2	6
1-3	6
1-4	6
1-5	6
1-6	6
1-7	6
1-8	7
1-9	6
1-10	6
1-11	6
1-12	6
1-13	6
1-14	6
1-15	6
1-16	6
1-17	6
1-18	6
1-19	6
1-20	6
1-21	6
1-22	6

Page	Active Revision
1-23	6
VCC-24-001, Sht. 1/2	6
VCC-24-001, Sht. 2/2	4
VCC-24-002, Sht. 1/3	5
VCC-24-002, Sht. 2/3	5
VCC-24-002, Sht. 3/3	3
VCC-24-003, Sht. 1/1	2
VCC-24-004, Sht. 1/1	2
VCC-24-005, Sht. 1/1	2
VCC-24-006, Sht. 1/2	5
VCC-24-006, Sht. 2/2	3
VCC-24-008, Sht. 1/1	3
MSB-24-001, Sht. 1/2	6
MSB-24-001, Sht. 2/2	5
MSB-24-002, Sht. 1/2	6
MSB-24-002, Sht. 2/2	4
MSB-24-003, Sht. 1/1	6
MSB-24-004, Sht. 1/3	6
MSB-24-004, Sht. 2/3	1
MSB-24-004, Sht. 3/3	4
MTC-24-001, Sht. 1/2	5
MTC-24-001, Sht. 2/2	5
MTC-24-002, Sht. 1/2	5

Page	Active Revision
MTC-24-002, Sht. 2/2	5
MTC-24-003, Sht. 1/2	3
MTC-24-003, Sht. 2/2	3
MTC-24-005, Sht. 1/1	4
MTC-24-006, Sht. 1/1	2
MTC-24-007, Sht. 1/1	5
MTC-24-008, Sht. 1/1	5
MTC-24-009, Sht. 1/2	3
MTC-24-009, Sht. 2/2	0
MTC-24-010, Sht. 1/2	2
MTC-24-010, Sht. 2/2	2
2-1	6
2-2	6
2-3	6
2-4	6
2-5	6
2-6	6
2-7	6
2-8	6
2-9	6
2-10	6
2-11	6
2-12	6
2-13	6
2-14	6
2-15	6
2-16	6
2-17	6
2-18	6
2-19	6
2-20	6
2-21	6
2-22	6
2-23	6

LIST OF EFFECTIVE PAGES

Page	Active Revision
2-24	6
2-25	6
3-1	6
3-2	6
3-3	6
3-4	6
3-5	6
3-6	6
3-7	6
3-8	6
3-9	6
3-10	6
3-11	6
3-12	6
3-13	6
3-14	6
3-15	6
3-16	6
3-17	6
3-18	6
3-19	6
3-20	6
3-21	6
3-22	6
3-23	6
3-24	6
3-25	6
3-26	6
3-27	6
3-28	6
3-29	6
3-30	6
3-31	6
3-32	6
3-33	6
3-34	6
3-35	6
3-36	6
4-1	6
4-2	6
4-3	6
4-4	6
4-5	6
4-6	6

Page	Active Revision
4-7	6
4-8	6
4-9	6
4-10	6
4-11	6
4-12	6
4-13	6
4-14	6
4-15	6
4-16	6
4-17	6
4-18	6
4-19	6
4-20	6
4-21	6
4-22	6
4-23	6
4-24	6
4-25	6
4-26	6
5-1	6
5-2	6
5-3	6
5-4	6
5-5	6
5-6	6
5-7	6
5-8	6
5-9	6
5-10	6
5-11	6
5-12	6
5-13	6
5-14	6
5-15	6
5-16	6
5-17	6
5-18	6
5-19	6
5-20	6
5-21	6
5-22	6
5-23	6
5-24	6

Page	Active Revision
5-25	6
5-26	6
5-27	6
5-28	6
5-29	6
5-30	6
5-31	6
5-32	6
5-33	6
5-34	6
5-35	6
5-36	6
5-37	6
5-38	6
5-39	6
5-40	6
5-41	6
5-42	6
6-1	6
6-2	6
6-3	6
6-4	6
6-5	6
6-6	6
6-7	6
6-8	6
6-9	6
6-10	6
6-11	6
6-12	6
6-13	6
6-14	6
6-15	6
6-16	6
6-17	6
6-18	6
6-19	6
6-20	6
6-21	6
6-22	6
6-23	6
6-24	6
6-25	6
6-26	6

LIST OF EFFECTIVE PAGES

Page	Active Revision
6-27	6
6-28	6
6-29	6
6-30	6
6-31	6
6-32	6
6-33	6
6-34	6
6-35	6
6-36	6
6-37	6
6-38	6
6-39	6
6-40	6
6-41	6
6-42	6
6-43	6
6-44	6
6-45	6
6-46	6
6-47	6
6-48	6
6-49	6
6-50	6
6-51	6
6-52	6
6-53	6
6-54	6
6-55	6
6-56	6
6-57	6
6-58	6
6-59	6
6-60	6
6-61	6
6-62	6
6-63	6
6-64	6
7-1	6
7-2	6
7-3	6
7-4	6
7-5	6
7-6	6

Page	Active Revision
7-7	6
7-8	6
7-9	6
7-10	6
7-11	6
7-12	6
7-13	6
7-14	6
7-15	6
7-16	6
8-1	6
8-2	6
8-3	6
8-4	6
8-5	6
8-6	6
8-7	6
8-8	6
9-1	6
9-2	6
9-3	6
10-1	6
10-2	6
10-3	6
10-4	6
10-5	6
10-6	6
10-7	6
10-8	6
10-9	6
10-10	6
10-11	6
10-12	6
10-13	6
10-14	6
10-15	6
11-1	6
11-2	6
11-3	6
11-4	6
11-5	6
11-6	6
11-7	6
11-8	6

Page	Active Revision
11-9	6
11-10	6
11-11	6
11-12	6
11-13	6
11-14	6
11-15	6
11-16	6
11-17	6
11-18	6
11-19	6
11-20	6
11-21	6
11-22	6
11-23	6
11-24	6
11-25	6
11-26	6
11-27	6
11-28	6
11-29	6
11-30	6
11-31	6
11-32	6
11-33	6
11-34	6
12-1	6
12-2	6
TOC-ii	6
TOC-iii	6
TS-1	6
TS-2	6
TS-3	6
TS-4	6
TS-5	6
TS-6	6
TS-7	6
TS-8	6
TS-9	6
TS-10	6
TS-11	6
TS-12	6
TS-13	6
TS-14	6

LIST OF EFFECTIVE PAGES

Page	Active Revision
TS-15	6
TS-16	6
TS-17	6
TS-18	6
TS-19	6
TS-20	6
TS-21	6
TS-22	6
TS-23	6
TS-24	6
TS-25	6
TS-26	6
TS-27	6
TS-28	6
TS-29	6
TS-30	6
TS-31	6
TS-32	6
TS-33	6
TS-34	6
TS-35	6
TS-36	6
TS-37	6
TS-38	6
TS-39	6
TS-40	6
TS-41	6
TS-42	6
TS-43	6
TS-44	6
TS-45	6
TS-46	6
TS-47	6
TS-48	6
TS-49	6
TS-50	6
TS-51	6
TS-52	6
TS-53	6
TS-54	6
TS-55	6
TS-56	6
TS-57	6
TS-58	6

Page	Active Revision
TS-59	6
TS-60	6
TS-61	6
TS-62	6
TS-63	6
TS-64	6
TS-65	6
TS-66	6
TS-67	6
13-1	7
14-1	6
14-2	6
14-3	6
14-4	6
14-5	6
A-1	6
A-2	6
A-3	6
A-4	6
A-5	6
B-1	6
B-2	6
B-3	6
B-4	6
B-5	6
C-1	6
C-2	6
C-3	6
D-1	6
D-2	6
D-3	6
D-4	6
F-1	6
Specification VMSB-98- 001	5

2. Load fuel assemblies in the MSB.
3. Place shielding lid on MSB and use transfer cask to remove MSB from fuel pool.
4. Close MSB. (See discussion in Chapter 8.)
5. Transfer MSB to concrete cask.
6. Close VCC.
7. Move VCC to storage location via truck trailer.
8. Position VCC at storage site via hydraulic roller skid.

Safe storage of the irradiated fuel in the VSC-24 System is provided by the removal of decay heat by convection, radiation, and conduction from the fuel rods to the MSB shell wall and the subsequent natural convection in the MSB-VCC annulus. Radiation exposure to site personnel is limited by the steel and concrete shielding. VSC-24 System operation is totally passive. No active systems are required.

The handling equipment required to implement the VSC-24 System is site-specific. This equipment includes an overhead handling crane at the reactor fuel pool, one transfer cask, one hydraulic roller skid, one yoke, and one transfer trailer. All equipment is designed and tested to applicable government and industrial standards and will be maintained and operated to the owner's specifications.

1.2.3 CASK CONTENTS

The fuel to be stored in the VSC-24 System is described in Section 2.1 of this FSAR. In addition to the fuel, the MSB will contain a helium cover gas.

1.3 IDENTIFICATION OF AGENTS AND CONTRACTORS

The owner of the design and Certificate of Compliance for the VSC-24 Ventilated Storage System is EnergySolutions Spent Fuel Division, Inc. (EnergySolutions SFD). EnergySolutions SFD is a wholly owned subsidiary of EnergySolutions LLC. All design and specification activities including quality assurance services continue to be performed by EnergySolutions SFD. Fabrication of the steel components (MSB, MTC) will be by a qualified steel fabrication shop chosen through a competitive bidding process. Fabrication of the VCC will be performed by a local concrete contractor, also chosen by the bid process. EnergySolutions SFD will retain full responsibility and control over all design, analysis, and fabrication activities.

Additional agents/contractors that may build and deliver VSC-24 systems and components are Wisconsin Electric Power Company of Milwaukee, Wisconsin. Wisconsin Electric Power Company will only build the VSC-24 systems and components for their own use and will build them under their own 10 CFR 50 Appendix B QA Program. EnergySolutions SFD will build casks and components for other users under the Manual of Quality Assurance referenced in Chapter 13 of this FSAR.

13.0 QUALITY ASSURANCE

EnergySolutions SFD will apply its Manual of Quality Assurance as approved by the Nuclear Regulatory Commission for Subpart G of the 10CFR Part 72.