

3	DESIGN OF STRUCTURES, COMPONENTS, EQUIPMENT AND SYSTEMS	1
3.1	CONFORMANCE WITH NRC GENERAL DESIGN CRITERIA	2
3.1.1	ATOMIC INDUSTRIAL FORUM DESIGN CRITERIA	2
3.1.1.1	Overall Plant Requirements	2
3.1.1.1.1	Quality Standards	2
3.1.1.1.2	Performance Standards	4
3.1.1.1.3	Fire Protection	5
3.1.1.1.4	Sharing of Systems	5
3.1.1.1.5	Records Requirements	5
3.1.1.2	Protection by Multiple Fission Product Barriers	6
3.1.1.2.1	Reactor Core Design	6
3.1.1.2.2	Suppression of Power Oscillations	7
3.1.1.2.3	Overall Power Coefficient	7
3.1.1.2.4	Reactor Coolant Pressure Boundary	7
3.1.1.2.5	Reactor Containment	8
3.1.1.3	Nuclear and Radiation Controls	9
3.1.1.3.1	Control Room	9
3.1.1.3.2	Instrumentation and Controls Systems	9
3.1.1.3.3	Fission Process Monitors and Controls	10
3.1.1.3.4	Core Protection Systems	11
3.1.1.3.5	Engineered Safety Features Protection Systems	11
3.1.1.3.6	Monitoring Reactor Coolant Leakage	12
3.1.1.3.7	Monitoring Radioactivity Releases	13
3.1.1.3.8	Monitoring Fuel and Waste Storage	13
3.1.1.4	Reliability and Testability of Protection Systems	14
3.1.1.4.1	Protection Systems Reliability	14
3.1.1.4.2	Protection Systems Redundancy and Independence	15
3.1.1.4.2.1	Reactor Trip Circuits	15
3.1.1.4.2.2	Engineered Safety Features Initiation Circuits	15
3.1.1.4.3	Single-Failure Definition (Category B)	16
3.1.1.4.4	Separation of Protection and Control Instrumentation Systems	16
3.1.1.4.5	Protection Against Multiple Disability for Protection Systems	16
3.1.1.4.6	Emergency Power for Protection Systems	16
3.1.1.4.7	Demonstration of Functional Operability of Protection Systems	17
3.1.1.4.8	Protection Systems Failure Analysis Design	17

3.1.1.5	Reactivity Control	18
3.1.1.5.1	Redundancy of Reactivity Control	18
3.1.1.5.2	Reactivity Hot Shutdown Capability	18
3.1.1.5.3	Reactivity Shutdown Capability	18
3.1.1.5.4	Reactivity Hold-Down Capability	19
3.1.1.5.5	Reactivity Control Systems Malfunction	19
3.1.1.5.6	Maximum Reactivity Worth of Control Rods	20
3.1.1.6	Reactor Coolant Pressure Boundary	20
3.1.1.6.1	Reactor Coolant Pressure Boundary Capability	20
3.1.1.6.2	Reactor Coolant Pressure Boundary Rapid Propagation Failure Prevention	21
3.1.1.6.3	Reactor Coolant Pressure Boundary Brittle Fracture Prevention	22
3.1.1.6.4	Reactor Coolant Pressure Boundary Surveillance	22
3.1.1.7	Engineered Safety Features	23
3.1.1.7.1	Engineered Safety Features Basis for Design	23
3.1.1.7.2	Reliability and Testability of Engineered Safety Features	24
3.1.1.7.3	Emergency Power	24
3.1.1.7.4	Missile Protection	25
3.1.1.7.5	Engineered Safety Features Performance Capability	26
3.1.1.7.6	Engineered Safety Features Components Capability	26
3.1.1.7.7	Accident Aggravation Prevention	27
3.1.1.7.8	Emergency Core Cooling System (ECCS) Capability	27
3.1.1.7.9	Inspection of Emergency Core Cooling System (ECCS)	28
3.1.1.7.10	Testing of Emergency Core Cooling System (ECCS) Components	28
3.1.1.7.11	Testing of Emergency Core Cooling System (ECCS)	28
3.1.1.7.12	Testing of Operational Sequence of Emergency Core Cooling System (ECCS)	28
3.1.1.7.13	Containment Design Basis	29
3.1.1.7.14	Nil Ductility Transition Temperature Requirement for Containment Material	29
3.1.1.7.15	Reactor Coolant Pressure Boundary Outside Containment	30
3.1.1.7.16	Containment Heat Removal Systems	30
3.1.1.7.17	Containment Isolation Valves	30
3.1.1.7.18	Initial Leakage Rate Testing of Containment	30
3.1.1.7.19	Periodic Containment Leakage Rate Testing	31
3.1.1.7.20	Provisions for Testing of Penetrations	31
3.1.1.7.21	Provisions for Testing of Isolation Valves	31

	GINNA/UFSAR	
3.1.1.7.22	Inspection of Containment Pressure-Reducing Systems	32
3.1.1.7.23	Testing of Containment Pressure-Reducing Systems Components	32
3.1.1.7.24	Testing of Containment Spray Systems	32
3.1.1.7.25	Testing of Operational Sequence of Containment Pressure-Reducing Systems	32
3.1.1.7.26	Inspection of Air Cleanup Systems	33
3.1.1.7.27	Testing of Air Cleanup Systems Components	33
3.1.1.7.28	Testing Air Cleanup System	33
3.1.1.7.29	Testing of Operational Sequence of Air Cleanup Systems	33
3.1.1.8	Fuel and Waste Storage Systems	34
3.1.1.8.1	Prevention of Fuel Storage Criticality	34
3.1.1.8.2	Fuel and Waste Storage Decay Heat	34
3.1.1.8.3	Fuel and Waste Storage Radiation Shielding	35
3.1.1.8.4	Protection Against Radioactivity Release From Spent Fuel and Waste Storage	35
3.1.1.9	Control of Releases of Radioactivity to the Environment	35
3.1.2	GENERAL DESIGN CRITERIA	36
3.1.2.1	Overall Requirements	36
3.1.2.1.1	General Design Criterion 1 - Quality Standards and Records	37
3.1.2.1.2	General Design Criterion 2 - Design Bases for Protection Against Natural Phenomena	38
3.1.2.1.3	General Design Criterion 3 - Fire Protection	38
3.1.2.1.4	General Design Criterion 4 - Environmental and Missile Design Bases	39
3.1.2.1.5	General Design Criterion 5 - Sharing of Structures, Systems, and Components	39
3.1.2.2	Protection by Multiple Fission Product Barriers	39
3.1.2.2.1	General Design Criterion 10 - Reactor Design	39
3.1.2.2.2	General Design Criterion 11 - Reactor Inherent Protection	40
3.1.2.2.3	General Design Criterion 12 - Suppression of Reactor Power Oscillations	40
3.1.2.2.4	General Design Criterion 13 - Instrumentation and Control	40
3.1.2.2.5	General Design Criterion 14 - Reactor Coolant Pressure Boundary	41
3.1.2.2.6	General Design Criterion 15 - Reactor Coolant System Design	41
3.1.2.2.7	General Design Criterion 16 - Containment Design	42
3.1.2.2.8	General Design Criterion 17 - Electrical Power Systems	42
3.1.2.2.9	General Design Criterion 18 - Inspection and Testing of Electrical Power Systems	44
3.1.2.2.10	General Design Criterion 19 - Control Room	44

3.1.2.3	Protection and Reactivity Control Systems	45
3.1.2.3.1	General Design Criterion 20 - Protection Systems Functions	45
3.1.2.3.2	General Design Criterion 21 - Protection System Reliability and Test-ability	45
3.1.2.3.3	General Design Criterion 22 - Protection System Independence	46
3.1.2.3.4	General Design Criterion 23 - Protection System Failure Modes	46
3.1.2.3.5	General Design Criterion 24 - Separation of Protection and Control Systems	47
3.1.2.3.6	General Design Criterion 25 - Protection System Requirements for Reactivity Control Malfunctions	47
3.1.2.3.7	General Design Criterion 26 - Reactivity Control System Redundancy and Capability	48
3.1.2.3.8	General Design Criterion 27 - Combined Reactivity Control System Capability	48
3.1.2.3.9	General Design Criterion 28 - Reactivity Limits	49
3.1.2.3.10	General Design Criterion 29 - Protection Against Anticipated Operational Occurrences	49
3.1.2.4	Fluid Systems	49
3.1.2.4.1	General Design Criterion 30 - Quality of Reactor Coolant Pressure Boundary	49
3.1.2.4.2	General Design Criterion 31 - Fracture Prevention of Reactor Coolant Pressure Boundary	50
3.1.2.4.3	General Design Criterion 32 - Inspection of Reactor Coolant Pressure Boundary	51
3.1.2.4.4	General Design Criterion 33 - Reactor Coolant Makeup	51
3.1.2.4.5	General Design Criterion 34 - Residual Heat Removal	52
3.1.2.4.6	General Design Criterion 35 - Emergency Core Cooling	52
3.1.2.4.7	General Design Criterion 36 - Inspection of Emergency Core Cooling System (ECCS)	53
3.1.2.4.8	General Design Criterion 37 - Testing of Emergency Core Cooling Systems (ECCS)	53
3.1.2.4.9	General Design Criterion 38 - Containment Heat Removal	54
3.1.2.4.10	General Design Criterion 39 - Inspection of Containment Heat Removal System	54
3.1.2.4.11	General Design Criterion 40 - Testing of Containment Heat Removal System	54
3.1.2.4.12	General Design Criterion 41 - Containment Atmosphere Cleanup	55
3.1.2.4.13	General Design Criterion 42 - Inspection of Containment Atmosphere Cleanup Systems	56
3.1.2.4.14	General Design Criterion 43 - Testing of Containment Atmosphere Cleanup Systems	56
3.1.2.4.15	General Design Criterion 44 - Cooling Water	57

3.1.2.4.16	General Design Criterion 45 - Inspection of Cooling Water System	57
3.1.2.4.17	General Design Criterion 46 - Testing of Cooling Water System	58
3.1.2.5	Reactor Containment	58
3.1.2.5.1	General Design Criterion 50 - Containment Design Basis	58
3.1.2.5.2	General Design Criterion 51 - Fracture Prevention of Containment Pressure Boundary	59
3.1.2.5.3	General Design Criterion 52 - Capability for Containment Leakage Rate Testing	59
3.1.2.5.4	General Design Criterion 53 - Provisions for Containment Testing and Inspection	59
3.1.2.5.5	General Design Criterion 54 - Piping Systems Penetrating Containment	60
3.1.2.5.6	General Design Criterion 55 - Reactor Coolant Pressure Boundary Penetrating Containment	60
3.1.2.5.7	General Design Criterion 56 - Primary Containment Isolation	61
3.1.2.5.8	General Design Criterion 57 - Closed System Isolation Valves	62
3.1.2.6	Fuel and Radioactivity Control	62
3.1.2.6.1	General Design Criterion 60 - Control of Releases of Radioactive Materials to the Environment	62
3.1.2.6.2	General Design Criterion 61 - Fuel Storage and Handling and Radioactivity Control	62
3.1.2.6.3	General Design Criterion 62 - Prevention of Criticality in Fuel Storage and Handling	63
3.1.2.6.4	General Design Criterion 63 - Monitoring Fuel and Waste Storage	63
3.1.2.6.5	General Design Criterion 64 - Monitoring Radioactivity Releases	64
3.2	CLASSIFICATION OF STRUCTURES, COMPONENTS, AND SYSTEMS	66
3.2.1	INTRODUCTION	66
3.2.2	SYSTEMATIC EVALUATION PROGRAM EVALUATION	66
3.2.2.1	Fracture Toughness	67
3.2.2.1.1	Pressurizer	67
3.2.2.1.2	Accumulators	68
3.2.2.1.3	Component Cooling Water (CCW) Pumps	68
3.2.2.1.4	Service Water Pumps	68
3.2.2.1.5	Main Steam Piping and Valves	69
3.2.2.1.6	Feedwater Piping and Valves	69
3.2.2.2	Radiography Requirements	69
3.2.2.2.1	Class 2 Pressure Vessels	69
3.2.2.2.2	Class 1 and 2 Welded Joints	70
3.2.2.2.3	Main Steam and Feedwater Piping	70

3.2.2.3	Valve Design	71
3.2.2.4	Pump Design	71
3.2.2.5	Storage Tank Design	72
Table 3.2-1	CLASSIFICATION OF STRUCTURES, SYSTEMS, AND COMPONENTS	74
3.3	WIND AND TORNADO LOADINGS	84
3.3.1	INTRODUCTION	84
3.3.2	STRUCTURAL UPGRADE PROGRAM EVALUATION	84
3.3.2.1	Structural Evaluation Approach	84
3.3.2.1.1	Requirements	84
3.3.2.1.2	Structural Evaluation Process	84
3.3.2.1.3	Structural Evaluation Computer Program	85
3.3.2.1.4	Input Load Criteria	85
3.3.2.1.5	General Assumptions	86
3.3.2.1.6	Load Combinations and Acceptance Criteria	87
3.3.2.2	Structural Evaluation	88
3.3.2.2.1	Primary Member Evaluation	88
3.3.2.2.2	Secondary Member Evaluation	89
3.3.2.2.3	Connections and Anchorages Evaluation	89
3.3.2.2.4	Exterior Shell Evaluation	90
3.3.2.2.4.1	Siding	90
3.3.2.2.4.2	Concrete Masonry Block Walls	90
3.3.2.2.4.3	Architectural Items	91
3.3.2.3	Results of the Structural Evaluation	91
3.3.2.3.1	Primary Members	91
3.3.2.3.1.1	General	91
3.3.2.3.1.2	Severe Environmental Conditions	91
3.3.2.3.1.3	Extreme Snow Load Condition	92
3.3.2.3.1.4	132-mph Tornado	92
3.3.2.3.1.5	188-mph Tornado	92
3.3.2.3.1.6	250-mph Tornado	92
3.3.2.3.2	Secondary Members	93
3.3.2.3.3	Connections and Anchorages	93
3.3.2.3.4	Exterior Shell	94
3.3.2.3.4.1	Metal Siding	94
3.3.2.3.4.2	Roof Decking	94

3.3.2.3.4.3	Block Walls	94
3.3.3	TORNADO MISSILES AND SAFE SHUTDOWN APPROACH	94
3.3.3.1	Background	94
3.3.3.2	Shutdown Methodology	95
3.3.3.2.1	Assumptions	95
3.3.3.2.2	Shutdown Details	95
3.3.3.3	Required Components	96
3.3.3.3.1	Refueling Water Storage Tank (RWST)	96
3.3.3.3.2	Electrical Buses 14, 17, and 18	96
3.3.3.3.3	Main Steam Lines A and B, and Main Feedwater Lines A and B	97
3.3.3.3.3.1	Results - Steel Rod	97
3.3.3.3.3.2	Results - Utility Pole	97
3.3.3.3.3.3	Failure of Block Walls	97
3.3.3.3.4	Surface of the Spent Fuel Pool	98
3.3.3.3.5	Diesel Generators and Their Fuel Supply	98
3.3.3.3.6	Relay Room	98
3.3.3.3.7	Service Water System	99
3.3.3.3.8	Standby Auxiliary Feedwater System	99
3.3.3.3.9	Instrumentation	99
3.3.3.3.10	Cable Tunnel	100
3.3.4	DESIGN TORNADO	100
3.3.4.1	Introduction	100
3.3.4.2	Safety Assessment	100
3.3.4.3	Reserve Plant Capacity	101
3.3.4.4	System Reserve Capacity	102
3.3.5	STRUCTURAL UPGRADE PROGRAM	103
3.3.5.1	Introduction	103
3.3.5.2	Criteria Changes	103
3.3.5.2.1	First Stage Review	103
3.3.5.2.2	Second Stage Review	104
3.3.5.3	Stability Evaluation	105
3.3.5.3.1	Primary Members	105
3.3.5.3.2	Connections and Anchorages	105
3.3.5.4	NRC Technical Evaluation Report (SEP Topic III-2) Open Items	106
3.3.5.4.1	Effective Tornado Loadings	106
3.3.5.4.2	Structural Loadings	107

3.3.5.4.3	Structural Acceptance Criteria	107
3.3.5.4.4	Structural Systems	107
3.3.5.5	SEP Topic III-7.B, Loads, Load Combinations, and Design Criteria	108
3.3.5.6	Diesel Generator Component Operability	109
3.3.5.7	Conclusions	109
3.3.6	INTERMEDIATE BUILDING BLOCK WALL REINFORCEMENT	110
Table 3.3-1	PRIMARY MEMBER FAILURES PER LOADING COMBINATION	114
3.4	WATER LEVEL (FLOOD) DESIGN	115
3.4.1	FLOOD PROTECTION	115
3.4.1.1	Flood Protection Measures for Seismic Category I Structures	115
3.4.1.1.1	Introduction	115
3.4.1.1.2	Lake Ontario Flood Protection	115
3.4.1.1.3	Deer Creek Flood Protection	116
3.4.1.2	Permanent Dewatering System	116
3.4.2	FLOODING DUE TO FAILURE OF TANKS	117
3.4.3	ROOF DRAINAGE	117
3.5	MISSILE PROTECTION	120
3.5.1	INTERNALLY GENERATED MISSILES	120
3.5.1.1	Introduction	120
3.5.1.1.1	Design Criteria	120
3.5.1.1.2	Systematic Evaluation Program	120
3.5.1.2	Turbine Missiles	121
3.5.1.2.1	Introduction	121
3.5.1.2.2	Turbine Inspection Program	122
3.5.1.2.3	Systematic Evaluation Program Topic III-4	122
3.5.1.3	Effects of Internally Generated Missiles on Systems and Equipment	123
3.5.1.3.1	Systems Needed to Perform Safety Functions	123
3.5.1.3.1.1	Reactor Coolant System	123
3.5.1.3.1.2	Emergency Core Cooling System (ECCS)	124
3.5.1.3.1.3	Containment Heat Removal and Atmosphere Cleanup Systems	125
3.5.1.3.1.4	Chemical and Volume Control System	126
3.5.1.3.1.5	Residual Heat Removal System	127
3.5.1.3.1.6	Component Cooling Water System	127
3.5.1.3.1.7	Service Water System	127
3.5.1.3.1.8	Diesel-Generator Auxiliary Systems	128

3.5.1.3.1.9	Main Steam System	128
3.5.1.3.1.10	Feedwater and Condensate Systems	129
3.5.1.3.1.11	Preferred Auxiliary Feedwater System	129
3.5.1.3.1.12	Standby Auxiliary Feedwater System (SAFW)	129
3.5.1.3.1.13	Ventilation Systems for Vital Areas	130
3.5.1.3.1.14	Combustible Gas Control System	130
3.5.1.3.2	Systems Whose Failure May Result in Activity Release	130
3.5.1.3.2.1	Spent Fuel Pool Cooling System	130
3.5.1.3.2.2	Sampling System	131
3.5.1.3.2.3	Waste Disposal System	131
3.5.1.3.2.4	Containment Shutdown Purge System	131
3.5.1.3.2.5	Instrument and Service Air Systems	131
3.5.1.3.3	Electrical Systems	132
3.5.1.3.3.1	Diesel Generators	132
3.5.1.3.3.2	Station Batteries	132
3.5.1.3.3.3	480-Volt Switchgear	132
3.5.1.3.3.4	Control Room	132
3.5.1.3.3.5	Cable Spreading/Relay Room	132
3.5.2	EXTERNALLY GENERATED MISSILES	133
3.5.2.1	Tornado Missiles	133
3.5.2.2	Site Proximity Missiles	133
3.5.2.2.1	Design Criteria	133
3.5.2.2.2	Nearby Hazardous Activities	133
3.5.2.2.3	Aircraft Hazards	134
3.6	PROTECTION AGAINST THE DYNAMIC EFFECTS ASSOCIATED WITH THE POSTULATED RUPTURE OF PIPING	136
3.6.1	POSTULATED PIPING FAILURES IN FLUID SYSTEMS INSIDE CONTAINMENT	136
3.6.1.1	Evaluation Procedure	136
3.6.1.1.1	Pipe Selection	136
3.6.1.1.2	Effects-Oriented Evaluation	137
3.6.1.1.3	Mechanistic Evaluation	137
3.6.1.2	Required Equipment	138
3.6.1.3	Safety Analysis	138
3.6.1.3.1	Single-Failure Considerations	138
3.6.1.3.1.1	Introduction	138
3.6.1.3.1.2	Containment Fan Coolers	139

3.6.1.3.1.3	Low-Pressure Safety Injection Isolation Valves	139
3.6.1.3.2	High-Energy Line Break Effects	139
3.6.1.3.2.1	Introduction	139
3.6.1.3.2.2	Alternate Charging	140
3.6.1.3.2.3	Residual Heat Removal Pump Suction	140
3.6.1.3.2.4	Reactor Coolant Pump Seal-Water to Seals	141
3.6.1.3.2.5	Letdown Line	141
3.6.1.3.2.6	Charging Line	142
3.6.1.3.2.7	Steam Generator Blowdown Lines	143
3.6.1.3.2.8	Main Steam and Feedwater Lines	143
3.6.1.3.2.9	Residual Heat Removal Pump Discharge Line	146
3.6.1.3.2.10	Standby Auxiliary Feedwater Lines	146
3.6.1.3.2.11	Accumulator Lines and Branch Lines	146
3.6.1.3.2.12	Auxiliary Spray Line	149
3.6.1.3.2.13	Reactor Coolant System	150
3.6.1.3.2.14	Pressurizer Surge Line	150
3.6.1.3.2.15	Pressurizer Spray Lines	153
3.6.1.3.2.16	Pressurizer Safety and Relief Lines	153
3.6.2	POSTULATED PIPING FAILURES IN FLUID SYSTEMS OUTSIDE CONTAINMENT	154
3.6.2.1	Introduction and Summary	154
3.6.2.1.1	Initial Evaluation	154
3.6.2.1.2	Systematic Evaluation Program Reevaluation	155
3.6.2.2	Evaluation Procedure	156
3.6.2.2.1	Initial Evaluation	156
3.6.2.2.2	Systematic Evaluation Program Reevaluation	157
3.6.2.3	Analysis Criteria	158
3.6.2.3.1	December 18, 1972, AEC Letter Evaluation Criteria	158
3.6.2.3.2	Systematic Evaluation Program Criteria	158
3.6.2.3.2.1	High-Energy Fluid Systems Piping	158
3.6.2.3.2.2	Moderate-Energy Fluid System Piping	160
3.6.2.3.2.3	Type of Breaks and Leakage Cracks in Fluid System Piping	161
3.6.2.3.2.4	Assumptions	162
3.6.2.3.2.5	Effects of Piping Failure	163
3.6.2.4	Analysis in Response to December 18, 1972, AEC Letter	163
3.6.2.4.1	Rupture Load Analysis	163

3.6.2.4.2	Main Steam System Load Analysis	164
3.6.2.4.3	Feedwater System Load Analysis	164
3.6.2.4.4	Jet Impingement Load Analysis	164
3.6.2.4.5	Pipe Whip Analysis for Main Steam and Feedwater Piping	165
3.6.2.4.5.1	Analytical Methods	165
3.6.2.4.5.2	Results of Analysis	165
3.6.2.4.6	Blowdown Analysis	166
3.6.2.4.6.1	Main Steam Blowdown Analysis	166
3.6.2.4.6.2	Feedwater Blowdown Analysis	166
3.6.2.4.7	Compartment Pressurization Analysis	167
3.6.2.4.7.1	Main Steam Line Ruptures	167
3.6.2.4.7.2	Building Pressurization for a Branch Line Rupture	167
3.6.2.4.8	Flooding Analysis	167
3.6.2.4.8.1	Intermediate Building Flooding	167
3.6.2.4.8.2	Screen House and Turbine Building Flooding	168
3.6.2.5	Systematic Evaluation Program Analysis	168
3.6.2.5.1	Zone Reevaluation Performed as Part of the Systematic Evaluation Program Review	168
3.6.2.5.1.1	Screen House	168
3.6.2.5.1.2	Intermediate Building	169
3.6.2.5.1.3	Turbine Building Main Steam and Main Feedwater Line Breaks	170
3.6.2.5.1.4	Structural Analysis of the Turbine Building for Pressurization	171
3.6.2.5.1.5	Battery Room/Mechanical Equipment Room Flooding	173
3.6.2.5.1.6	Auxiliary Feedwater Line Breaks on the 253-Ft Elevation of the Inter- Building	mediate 173
3.6.2.5.1.7	Relay Room and Air Handling Room	173
3.6.2.5.1.8	Auxiliary Building	174
3.6.2.5.2	Main Steam Safety and Relief Valves	175
3.6.2.5.2.1	Pipe Failures in the Intermediate Building	175
3.6.2.5.2.2	Pipe Failures in the Turbine Building	176
3.6.2.5.2.3	Decay Heat Removal Following Blowdown from Both Steam Generators	177
3.6.2.5.2.4	Conclusions	178
Table 3.6-1	LINES PENETRATING CONTAINMENT WHICH NORMALLY OR OCCASIONALLY EXPERIENCE HIGH-ENERGY SERVICE CONDITIONS	182

Table 3.6-2	LINES INSIDE CONTAINMENT BUT NOT PENETRATING CONTAINMENT WHICH NORMALLY OR OCCASIONALLY EXPERIENCE HIGH-ENERGY SERVICE CONDITIONS	184
Table 3.6-3	CONTAINMENT PIPE DATA	185
3.7	SEISMIC DESIGN	187
3.7.1	SEISMIC INPUT	187
3.7.1.1	Introduction	187
3.7.1.1.1	Original Seismic Classification	187
3.7.1.1.2	Seismic Reevaluation	188
3.7.1.1.2.1	Scope of Reevaluation	188
3.7.1.1.2.2	Reevaluation Criteria	188
3.7.1.2	Design Response Spectra	189
3.7.1.3	Design Time-History	189
3.7.1.4	Critical Damping Values	19
3.7.1.5	Supporting Media for Seismic Category I Structures	190
3.7.2	SEISMIC SYSTEM ANALYSIS	191
3.7.2.1	Seismic Analysis Methods	191
3.7.2.1.1	Original Seismic Analysis	191
3.7.2.1.2	Seismic Reevaluation	192
3.7.2.2	Natural Frequencies and Response Loads	193
3.7.2.3	Procedure Used for Mathematical Modeling	193
3.7.2.4	Soil-Structure Interaction	193
3.7.2.5	Development of Floor Response Spectra	193
3.7.2.6	Combination of Earthquake Directional Components	194
3.7.2.7	Combination of Modal Responses	194
3.7.2.8	Interaction of Nonseismic Structures with Seismic Category I Structures	194
3.7.2.9	Use of Constant Vertical Static Factors	195
3.7.3	SEISMIC SUBSYSTEM ANALYSIS	195
3.7.3.1	Seismic Analysis Methods	195
3.7.3.1.1	Original Design	195
3.7.3.1.1.1	Piping and Tanks	195
3.7.3.1.1.2	Steam Generator	196
3.7.3.1.1.3	Control Rod Drive Mechanisms	196
3.7.3.1.1.4	Reactor Internals	196
3.7.3.1.1.5	Reactor Vessel	197

3.7.3.1.1.6	Pressurizer	197
3.7.3.1.2	Seismic Reevaluation	198
3.7.3.2	Basis for Selection of Frequencies	199
3.7.3.3	Use of Equivalent Static Analysis	199
3.7.3.4	Three Components of Earthquake Motion	199
3.7.3.5	Combination of Modal Responses	200
3.7.3.6	Analytical Procedures for Piping	200
3.7.3.6.1	Residual Heat Removal System Line from Reactor Coolant System Loop A to Containment	200
3.7.3.6.2	Steam Line from Steam Generator B to Containment	201
3.7.3.6.3	Pressurizer Safety and Relief Lines	201
3.7.3.6.3.1	Analytical Methods	201
3.7.3.6.3.2	Transfer Matrix Method	202
3.7.3.6.3.3	Stiffness Matrix Formulation	203
3.7.3.7	Seismic Piping Upgrade Program	204
3.7.3.7.1	Program Scope	204
3.7.3.7.2	Piping Selection Criteria	204
3.7.3.7.3	Selected Lines	205
3.7.3.7.3.1	Reactor Coolant System	205
3.7.3.7.3.2	Main Steam	205
3.7.3.7.3.3	Main Feedwater	205
3.7.3.7.3.4	Auxiliary Feedwater	205
3.7.3.7.3.5	Safety Injection	206
3.7.3.7.3.6	Residual Heat Removal	206
3.7.3.7.3.7	Containment Spray	206
3.7.3.7.3.8	Chemical and Volume Control System	207
3.7.3.7.3.9	Steam Generator Blowdown	207
3.7.3.7.3.10	Service Water System	207
3.7.3.7.3.11	Component Cooling Water	208
3.7.3.7.3.12	Standby Auxiliary Feedwater	209
3.7.3.7.4	Codes and Standards	209
3.7.3.7.5	Analytical Procedures	209
3.7.3.7.5.1	General	209
3.7.3.7.5.2	Damping Values	209
3.7.3.7.5.3	Combination of Modal Responses	210
3.7.3.7.5.4	Safe Shutdown Earthquake Stresses	212

3.7.3.7.5.5	Small Piping Analysis	213
3.7.3.7.5.6	Branch Line Analysis	213
3.7.3.7.5.7	Piping Beyond Scope of Upgrade Program	213
3.7.3.7.6	Piping System Models	214
3.7.3.7.7	Valve Model	215
3.7.3.7.8	Equipment Model	215
3.7.3.7.9	Interaction Effects	215
3.7.3.7.10	Support Model	215
3.7.3.7.10.1	Deviations	215
3.7.3.7.10.2	Support-Welded Attachments	216
3.7.4	SEISMIC INSTRUMENTATION	217
Table 3.7-1	ORIGINAL AND CURRENT RECOMMENDED DAMPING VALUES	219
Table 3.7-2	MODAL FREQUENCIES OF THE INTERCONNECTED BUILDING MODEL	220
Table 3.7-3	EQUIPMENT AND LOCATIONS WHERE IN-STRUCTURE SPECTRA WERE GENERATED FOR THE SYSTEMATIC EVALUATION PROGRAM	222
3.8	DESIGN OF SEISMIC CATEGORY I STRUCTURES	223
3.8.1	CONTAINMENT	223
3.8.1.1	General Description	223
3.8.1.1.1	Containment Structure	223
3.8.1.1.2	Waterproofing	224
3.8.1.1.3	Rock Anchors	224
3.8.1.1.4	Construction Sequence	224
3.8.1.1.5	Steel Reinforcement	226
3.8.1.2	Mechanical Design Bases	227
3.8.1.2.1	General	227
3.8.1.2.2	Design Loads	227
3.8.1.2.3	Design Stress Criteria	228
3.8.1.2.3.1	Limiting Loads	228
3.8.1.2.3.2	Load Factors	229
3.8.1.2.3.3	Maximum Thermal Load	229
3.8.1.2.4	Load Capacity	230

3.8.1.2.4.1	Reinforced Concrete	230
3.8.1.2.4.2	Prestressed Concrete	232
3.8.1.2.4.3	Liner	233
3.8.1.2.4.4	Rock	234
3.8.1.2.5	Codes and Standards	234
3.8.1.2.5	Codes and Standards Steam Generator Replacement (Dome Opening Repairs	237
3.8.1.3	Seismic Design	239
3.8.1.3.1	Initial Seismic Design	239
3.8.1.3.2	Seismic Reanalysis	240
3.8.1.4	Containment Detailed Design	240
3.8.1.4.1	Stress Analysis	240
3.8.1.4.1.1	Analysis Methods	240
3.8.1.4.1.2	Analysis Results	241
3.8.1.4.1.3	Analysis for Steam Generator Replacement Dome Openings	242
3.8.1.4.2	Rock Anchors	242
3.8.1.4.2.1	Rock Anchor Design	242
3.8.1.4.2.2	Preinstallation Grouting Test	243
3.8.1.4.2.3	Previous Applications	244
3.8.1.4.2.4	Rock Hold-Down Capacity	244
3.8.1.4.2.5	Hold-Down Factor of Safety	246
3.8.1.4.2.6	Installation	246
3.8.1.4.3	Tendons	247
3.8.1.4.3.1	General Design	247
3.8.1.4.3.2	Seismic Considerations	249
3.8.1.4.3.3	Stressing Procedure	251
3.8.1.4.3.4	Corrosion Protection	252
3.8.1.4.4	Hinge Design	254
3.8.1.4.4.1	Tension Bars	254
3.8.1.4.4.2	Liner Knuckle	256
3.8.1.4.4.3	Elastomer Bearing Pads	257
3.8.1.4.5	Concrete	259
3.8.1.4.5.1	Radial Shear	259
3.8.1.4.5.2	Longitudinal Shears	259
3.8.1.4.5.3	Horizontal Shear	260
3.8.1.4.5.4	Anchorage Stresses	261

3.8.1.4.5.5	Shell Stress Analytical Procedures	262
3.8.1.4.6	Insulation	267
3.8.1.4.7	Liner	268
3.8.1.4.7.1	Vibrations	268
3.8.1.4.7.2	Anchorage Fatigue Analysis	268
3.8.1.4.7.3	Base Slab Liner	268
3.8.1.4.7.4	Liner Stresses	269
3.8.1.4.7.5	Liner Buckling	270
3.8.1.4.7.6	Liner Corrosion Allowance	274
3.8.1.5	Penetrations	274
3.8.1.5.1	General	274
3.8.1.5.2	Electrical Penetrations	275
3.8.1.5.3	Piping Penetrations	276
3.8.1.5.4	Access Hatch and Personnel Locks	276
3.8.1.5.5	Fuel Transfer Penetration	277
3.8.1.5.6	Typical Penetration Analysis	278
3.8.1.5.6.1	Loss-of-Coolant Accident	278
3.8.1.5.6.2	Loss-of-Coolant Accident Plus Earthquake	280
3.8.1.5.7	Penetration Reinforcement Analyzed for Pipe Rupture	281
3.8.1.6	Quality Control and Material Specifications	282
3.8.1.6.1	Concrete	282
3.8.1.6.1.1	Ultimate Compressive Strength	282
3.8.1.6.1.2	Quality Control Measures	282
3.8.1.6.1.3	Concrete Suppliers	283
3.8.1.6.1.4	Concrete Specifications	284
3.8.1.6.1.5	Admixtures	286
3.8.1.6.1.6	Replacement Concrete for the 1996 Steam Generator Replacement	287
3.8.1.6.2	Mild Steel Reinforcement	288
3.8.1.6.3	Cadwell Splices	289
3.8.1.6.4	Radial Tension Bars	290
3.8.1.6.5	Containment Liner	290
3.8.1.6.5.1	Fabrication and Workmanship	290
3.8.1.6.5.2	Penetrations	291
3.8.1.6.5.3	Welding	291
3.8.1.6.5.4	Erection Tolerances	292
3.8.1.6.5.5	Painting	292

3.8.1.6.6	Elastomer Pads	293
3.8.1.6.7	Tendons	293
3.8.1.6.7.1	Materials	293
3.8.1.6.7.2	Tests and Inspection	294
3.8.1.6.8	Liner Insulation	294
3.8.1.7	Testing and Inservice Inspection Requirements	295
3.8.1.7.1	Construction Phase Testing	295
3.8.1.7.1.1	Liner	295
3.8.1.7.1.2	Prestressing Tendons	296
3.8.1.7.1.3	Concrete Reinforcement	296
3.8.1.7.1.4	Concrete	297
3.8.1.7.1.5	Elastomer Bearing Pads	298
3.8.1.7.1.6	Rock Anchor Tests	299
3.8.1.7.1.7	Large Opening Reinforcements	300
3.8.1.7.1.8	Liner Insulation	300
3.8.1.7.2	General Description of the Structural Integrity Test	300
3.8.1.7.2.1	Pressurization	300
3.8.1.7.2.2	Measurements	301
3.8.1.7.2.3	Test Pressure Justification	303
3.8.1.7.2.4	Test Results	303
3.8.1.7.2.5	Containment Return to Service Testing Post 1996 Steam Generator Replacement	303
3.8.1.7.3	Postoperational Surveillance	304
3.8.1.7.3.1	Leakage Monitoring	304
3.8.1.7.3.2	Initial Tendon Surveillance Program	304
3.8.1.7.3.3	Current Tendon Surveillance Program	305
3.8.1.7.3.4	Current Tendon Surveillance Program Results	306
3.8.1.7.3.5	Test on Rock Anchors	307
3.8.1.7.3.6	Inservice Inspection	307
3.8.2	STRUCTURAL REANALYSIS PROGRAM	308
3.8.2.1	Design Codes, Criteria, and Load Combinations - SEP Topic III-7.B	308
3.8.2.1.1	Introduction	308
3.8.2.1.1.1	Seismic Category I Structures	308
3.8.2.1.1.2	Structural Codes	309
3.8.2.1.1.3	Code Comparison	311
3.8.2.1.2	Assessment of Design Codes and Load Changes for Concrete Structures	311

3.8.2.1.2.1	Columns With Spliced Reinforcing	311
3.8.2.1.2.2	Brackets and Corbels (Not on the Containment Shell)	312
3.8.2.1.2.3	Elements Loaded in Shear With No Diagonal Tension (Shear Friction)	313
3.8.2.1.2.4	Structural Walls - Primary Load Carrying	314
3.8.2.1.2.5	Elements Subject to Temperature Variations	315
3.8.2.1.2.6	Areas of Containment Shell Subject to Peripheral Shear	316
3.8.2.1.2.7	Areas of Containment Shell Subject to Torsion	317
3.8.2.1.2.8	Brackets and Corbels (On the Containment Shell)	317
3.8.2.1.2.9	Areas of Containment Shell Subject to Biaxial Tension	317
3.8.2.1.2.10	Steel Embedments Transmitting Loads to Concrete	318
3.8.2.1.3	Assessment of Design Codes and Load Changes for Steel Structures	318
3.8.2.1.3.1	Shear Connectors in Composite Beams	319
3.8.2.1.3.2	Composite Beams With Steel Deck	319
3.8.2.1.3.3	Hybrid Girders	319
3.8.2.1.3.4	Compression Elements	320
3.8.2.1.3.5	Tension Members	320
3.8.2.1.3.6	Coped Beams	320
3.8.2.1.3.7	Moment Connections	321
3.8.2.1.3.8	Lateral Bracing	321
3.8.2.1.3.9	Steel Embedments	321
3.8.2.1.4	Summary	323
3.8.2.2	Structural Reevaluation of Containment	323
3.8.2.2.1	Introduction	323
3.8.2.2.2	Containment Temperature	324
3.8.2.2.3	Containment Pressure	324
3.8.2.2.4	Seismic Loads	324
3.8.2.2.5	Design and Analysis Procedures	325
3.8.2.2.5.1	Containment Model	325
3.8.2.2.5.2	Seismic and Loss-of-Coolant Accident Loads	325
3.8.2.2.5.3	Pressure, Seismic, and Operating Temperature Loads	326
3.8.2.2.6	Structural Acceptance Criteria	327
3.8.2.2.7	Structural Evaluation of Containment	327
3.8.2.2.7.1	Seismic Analysis	327
3.8.2.2.7.2	Load Combinations	328
3.8.2.2.8	Structural Evaluation of Large Openings	329
3.8.2.2.9	Structural Evaluation of Tension Rods	329

3.8.2.3	Dome Liner Reevaluation	329
3.8.2.3.1	Dome Liner Studs	329
3.8.2.3.2	Loads	329
3.8.2.3.2.1	Loss-of-Coolant Accident	329
3.8.2.3.2.2	Steam Line Break	330
3.8.2.3.3	Model Definition	330
3.8.2.3.3.1	General Dome Model	330
3.8.2.3.3.2	Insulation Termination Region Model	330
3.8.2.3.4	Analysis	331
3.8.2.3.4.1	Controlling Loads	331
3.8.2.3.4.2	Liner-Stud Interaction	331
3.8.2.3.4.3	Effect of Internal Pressure on Liner Buckling	333
3.8.2.3.5	Results and Conclusions	334
3.8.2.3.5.1	Insulation Termination Region	334
3.8.2.3.5.2	General Dome	335
3.8.2.3.5.3	Effect of Internal Pressure on Liner Buckling and Stud Integrity	336
3.8.2.3.6	Overall Conclusions	338
3.8.3	CONTAINMENT INTERNAL STRUCTURES	338
3.8.3.1	Description of the Internal Structures	338
3.8.3.2	Applicable Codes, Standards, and Specifications	339
3.8.3.3	Loads and Load Combinations	339
3.8.3.3.1	Load Combinations Considered	339
3.8.3.3.2	Applicable Load Combinations	339
3.8.3.4	Design and Analysis Procedures	340
3.8.3.4.1	Original Design	340
3.8.3.4.2	Systematic Evaluation Program Reevaluation	341
3.8.3.5	Method of Analysis	341
3.8.3.6	Structural Acceptance Criteria	342
3.8.3.7	Structural Evaluation	342
3.8.4	OTHER SEISMIC CATEGORY I STRUCTURES	342
3.8.4.1	Description of the Structures	342
3.8.4.1.1	Auxiliary Building	343
3.8.4.1.2	Control Building	343
3.8.4.1.3	Diesel Generator Building	344
3.8.4.1.4	Intermediate Building	344

3.8.4.1.5	Standby Auxiliary Feedwater Building	345
3.8.4.1.6	Screen House	345
3.8.4.1.7	Turbine Building	346
3.8.4.1.8	Service Building	346
3.8.4.1.9	Interconnected Building Complex	347
3.8.4.1.10	Canister Preparation Building (CPB)	347
3.8.4.2	Applicable Codes, Standards, and Specifications	348
3.8.4.3	Loads and Load Combinations	348
3.8.4.4	Design and Analysis Procedures	348
3.8.4.4.1	Original Design and Analysis Procedures	348
3.8.4.4.2	SEP Reevaluation Design and Analysis Procedures	349
3.8.4.4.2.1	Mathematical Model	349
3.8.4.4.2.2	Method of Analysis	351
3.8.4.4.2.3	Structural Evaluation	352
3.8.4.5	Masonry Walls	353
3.8.4.5.1	Applicable Walls	353
3.8.4.5.2	Loads and Load Combinations	353
3.8.4.5.3	Stress Analysis	355
3.8.4.5.3.1	Computer Program	355
3.8.4.5.3.2	Seismic Analysis	355
3.8.4.5.4	Interstory Drift	356
3.8.4.5.5	Multi-Wythe Walls	356
3.8.4.5.6	Block Pullout	356
3.8.4.5.7	Structural Acceptance Criteria - Allowable Stresses	356
3.8.4.5.7.1	Normal Operating Conditions	356
3.8.4.5.7.2	Safe Shutdown Earthquake	357
3.8.4.5.8	Evaluation Results	357
3.8.4.5.8.1	General	357
3.8.4.5.8.2	Inelastic Analysis	358
3.8.4.5.8.3	Wall Modifications	358
3.8.4.5.9	Materials, Quality Control, and Special Construction Techniques	359
3.8.5	FOUNDATIONS	360
Table 3.8-1a	COMPUTER PROGRAM SAND INPUT FOR CONTAINMENT SEISMIC ANALYSIS - DIMENSIONS AND FORMULA	365

Table 3.8-1b	COMPUTER PROGRAM SAND INPUT FOR CONTAINMENT SEISMIC ANALYSIS - DIMENSION CALCULATIONS	366
Table 3.8-1c	COMPUTER PROGRAM SAND INPUT FOR CONTAINMENT SEISMIC ANALYSIS - NATURAL FREQUENCIES AND RESPONSE	367
Table 3.8-2	MAJOR STRUCTURES FOR WHICH PRESTRESSED ROCK ANCHORS WERE USED	368
Table 3.8-3	PROPERTIES AND TESTS FOR CONTAINMENT ANCHOR AND TENDON CORROSION INHIBITOR	370
Table 3.8-4	ALLOWABLE STRESSES	371
Table 3.8-5a	CONTAINMENT STRUCTURE STRESSES - LOADING #1 DEAD LOAD	372
Table 3.8-5b	CONTAINMENT STRUCTURE STRESSES - LOADING #2 FINAL PRESTRESS - 636 K/TENDON	373
Table 3.8-5c	CONTAINMENT STRUCTURE STRESSES - LOADING #3 OPERATING TEMPERATURE - WINTER	375
Table 3.8-5d	CONTAINMENT STRUCTURE STRESSES - LOADING #4 OPERATING TEMPERATURE - SUMMER	377
Table 3.8-5e	CONTAINMENT STRUCTURE STRESSES - LOADING #5 INTERNAL PRESSURE	378
Table 3.8-5f	CONTAINMENT STRUCTURE STRESSES - LOADING #6 ACCIDENT TEMPERATURE - P = 60 PSIG, T = 286°F	379
Table 3.8-5g	CONTAINMENT STRUCTURE STRESSES - LOADING #7 ACCIDENT TEMPERATURE - P = 90 PSIG, T = 312°F	380
Table 3.8-5h	CONTAINMENT STRUCTURE STRESSES - LOADING #8 0.10G EARTHQUAKE - HORIZONTAL + VERTICAL COMPONENT	382
Table 3.8-6a	CONTAINMENT STRUCTURE LOADING COMBINATIONS - LOAD NUMBERS 1 THROUGH 48	383
Table 3.8-6b	CONTAINMENT STRUCTURE LOADING COMBINATIONS - KEY TO SYMBOLS	385
Table 3.8-7	CONCRETE COVER REQUIRED FOR REINFORCING STEEL	385
Table 3.8-8	ELASTOMER PADS PROPERTIES	387
Table 3.8-9	ROCK ANCHOR A - UPLIFT TEST WITH JACKING FRAME, MAY 19, 1966	388
Table 3.8-10	DESIGN CODE COMPARISON	389
Table 3.8-11	ACI 318-63 VERSUS ACI 349-76 CODE COMPARISONS	391
Table 3.8-12	ACI 301-63 VERSUS ACI 301-72 (REVISED 1975) COMPARISON	393
Table 3.8-13	ACI 318-63 VERSUS ASME B&PV CODE, SECTION III, DIVISION 2, 1980 CODE COMPARISON	394
Table 3.8-14	ASME B&PV CODE, SECTION III, DIVISION 2, 1980 (ACI 359-80) VERSUS ACI 318-63 CODE COMPARISON	395
Table 3.8-15	LIST OF STRUCTURAL ELEMENTS TO BE EXAMINED	396

Table 3.8-16	MASSES, MOMENT OF INERTIA (I), FLEXURAL AREA (A), AND SHEAR AREA (A _s) FOR THE LLNL MODEL	398
Table 3.8-17	MODAL FREQUENCIES FOR THE LAWRENCE LIVERMORE NATIONAL LABORATORY CONTAINMENT SHELL MODEL	399
Table 3.8-18	RESPONSE VALUES FOR REGULATORY GUIDE 1.60 HORIZONTAL (0.17g) AND VERTICAL (0.11g) SPECTRA INPUT	400
Table 3.8-19	PEAK HARMONIC AMPLITUDES OF THE SEISMIC LOAD ON CYLINDER AND DOME OF THE CONTAINMENT SHELL	401
Table 3.8-20	MATERIAL PROPERTIES FOR STEEL, CONCRETE, AND FOAM INSULATION	402
Table 3.8-21	MAXIMUM DISPLACEMENTS OF 5/8-INCH S6L STUDS IN THE INSULATION TERMINATION REGION	403
Table 3.8-22	MAXIMUM DISPLACEMENT OF STUDS IN GENERAL DOME	404
Table 3.8-23	LOAD DEFINITIONS	405
3.9	MECHANICAL SYSTEMS AND COMPONENTS	406
3.9.1	SPECIAL TOPICS FOR MECHANICAL COMPONENTS	406
3.9.1.1	Design Transients	406
3.9.1.1.1	Load Combinations	406
3.9.1.1.2	Cyclic Loads	406
3.9.1.1.2.1	Thermal and Pressure Cyclic Loads	406
3.9.1.1.2.2	Pressurizer Surge Line	406
3.9.1.1.2.3	Unisolable Connections to the Reactor Coolant System	407
3.9.1.1.3	Transient Hydraulic Loads	408
3.9.1.1.4	Operating-Basis Earthquake	408
3.9.1.1.5	Safe Shutdown Earthquake	408
3.9.1.1.6	Secondary System Fluid Flow Instability (Water Hammer)	408
3.9.1.1.7	Loss-of-Coolant Accident	408
3.9.1.2	Computer Programs Used in Analysis	409
3.9.1.3	Experimental Stress Analysis	410
3.9.1.3.1	Plastic Model Analysis	410
3.9.1.3.2	Plastic Model Details	410
3.9.1.3.3	Plastic Model Test Arrangement	411
3.9.2	DYNAMIC TESTING AND ANALYSIS	412
3.9.2.1	Piping Systems	412
3.9.2.1.1	General	412
3.9.2.1.2	Seismic Category I Piping, 2-1/2 Inch Nominal Size and Larger	413
3.9.2.1.2.1	Static Analysis	413
3.9.2.1.2.2	Dynamic Analysis	413

3.9.2.1.2.3	Residual Heat Removal System Line From Reactor Coolant System Loop A to Containment	414
3.9.2.1.2.4	Steam Line From Steam Generator B to Containment	415
3.9.2.1.2.5	Charging Line	416
3.9.2.1.3	Seismic Category I Piping, 2-Inch Nominal Size and Under, Original Design	416
3.9.2.1.4	Pressurizer Safety and Relief Valve Discharge Piping	416
3.9.2.1.4.1	1972 Analysis	416
3.9.2.1.4.2	NUREG 0737, Item II.D.1 Analysis	417
3.9.2.1.5	Main Steam Header Dynamic Load Factor Analysis	418
3.9.2.1.5.1	Extended Power Uprate Considerations	419
3.9.2.1.6	Secondary System Water Hammer	419
3.9.2.1.6.1	Analysis	419
3.9.2.1.6.2	Evaluation Results	420
3.9.2.1.6.3	Corrective Actions	420
3.9.2.1.6.4	Extended Power Uprate Considerations	421
3.9.2.1.7	Velan Swing Check Valves	421
3.9.2.1.8	Seismic Piping Upgrade Program	421
3.9.2.2	Safety-Related Mechanical Equipment	422
3.9.2.2.1	Original Seismic Input and Behavior Criteria	422
3.9.2.2.2	Current Seismic Input	423
3.9.2.2.3	Systematic Evaluation Program	423
3.9.2.2.4	Systematic Evaluation Program Reevaluation of Selected Mechanical Components for Design Adequacy	424
3.9.2.2.4.1	Essential Service Water (SW) Pumps	424
3.9.2.2.4.2	Component Cooling Heat Exchanger	425
3.9.2.2.4.3	Component Cooling Surge Tank	425
3.9.2.2.4.4	Diesel-Generator Air Tanks	425
3.9.2.2.4.5	Boric Acid Storage Tank	426
3.9.2.2.4.6	Refueling Water Storage Tank (RWST)	426
3.9.2.2.4.7	Motor-Operated Valves	427
3.9.2.2.4.8	Steam Generators	427
3.9.2.2.4.9	Reactor Coolant Pumps	428
3.9.2.2.4.10	Pressurizer	428
3.9.2.2.4.11	Control Rod Drive Mechanism	429
3.9.2.3	Dynamic Response Analysis of Reactor Internals Under Operational Flow Transients and Steady-State Conditions	429

3.9.2.3.1	Design Criteria	430
3.9.2.3.1.1	General	430
3.9.2.3.1.2	Critical Internals	430
3.9.2.3.1.3	Allowable Stress Criteria	431
3.9.2.3.2	Blowdown and Force Analysis	431
3.9.2.3.2.1	Computer Program	431
3.9.2.3.2.2	Blowdown Model	432
3.9.2.3.2.3	LATFORC MODEL	433
3.9.2.3.2.4	FORCE2 MODEL	433
3.9.2.3.3	Fuel Assembly Thimbles	434
3.9.2.3.4	Dynamic System Analysis of Reactor Internals Under Loss-of-Coolant Accident (LOCA)	434
3.9.2.3.4.1	Mathematical Model of the Reactor Pressure Vessel (RPV) System	434
3.9.2.3.4.2	Analytical Methods	436
3.9.2.3.4.3	RPV Internal Hydraulic Loads	436
3.9.2.3.4.4	Reactor Coolant Loop Mechanical Loads	438
3.9.2.3.4.5	Results of the Analysis	438
3.9.2.3.5	Transverse Guide Tube Excitation by Blowdown Forces	438
3.9.2.3.5.1	General	438
3.9.2.3.5.2	Response of Guide Tube	439
3.9.2.3.5.3	Description of Stress Location	440
3.9.2.3.6	Reevaluation of the Dynamic Response of Reactor Internals for Extended Power Uprate (EPU)	440
3.9.2.3.6.1	Reactor Pressure Vessel System Thermal-Hydraulic Analysis	440
3.9.2.3.6.2	Bypass Flow Analysis	440
3.9.2.3.6.3	Thermal Analysis of the Baffle/Barrel Region	441
3.9.2.3.6.4	Pressure Drop Across the Baffle Plate Analyses	441
3.9.2.3.6.5	Flow Induced Vibration	441
3.9.2.3.6.6	Reactor Internals Structural Integrity	441
3.9.2.3.6.7	Control Rod Performance	441
3.9.2.3.6.8	Vessel/Internals/Fuel/Control Rod Response During Loca Conditions	442
3.9.2.3.6.9	Summary of Conclusions	442
3.9.2.4	Asymmetric Loss-of-Coolant Accident Loading Analysis	442
3.9.2.5	Seismic Evaluation of Reactor Vessel Internals	442
3.9.2.5.1	Analysis Procedure	442
3.9.2.5.2	Analysis Results	443

3.9.3	COMPONENT SUPPORTS AND CORE SUPPORT STRUCTURES	444
3.9.3.1	Loading Combinations, Design Transients, and Stress Limits	444
3.9.3.2	Component Supports	444
3.9.3.2.1	Reactor Vessel	444
3.9.3.2.2	Steam Generators	445
3.9.3.2.3	Reactor Coolant Pumps	445
3.9.3.2.4	Pressurizer	446
3.9.3.2.5	Reactor Coolant Piping	446
3.9.3.3	Pipe Supports	446
3.9.3.3.1	Original Analysis	446
3.9.3.3.2	IE Bulletin Reanalysis	446
3.9.3.3.3	Seismic Piping Upgrade Program	447
3.9.3.3.3.1	Applicable Supports	447
3.9.3.3.3.2	Load Combinations and Stress Limits	447
3.9.3.3.3.3	Structural Requirements	447
3.9.3.3.4	Base Plate Flexibility	449
3.9.3.3.5	Snubbers	449
3.9.3.3.5.1	Design Loads	449
3.9.3.3.5.2	Surveillance Program	450
3.9.4	CONTROL ROD DRIVE SYSTEMS	450
3.9.4.1	Description	450
3.9.4.1.1	General	450
3.9.4.1.2	Latch Assembly	451
3.9.4.1.3	Pressure Vessel	452
3.9.4.1.4	Operating Coil Stack	452
3.9.4.1.5	Drive Shaft Assembly	452
3.9.4.1.6	Position Indicator Coil Stack	452
3.9.4.2	Design Loads, Stress Limits, and Allowable Deformation	452
3.9.4.3	Control Rod Drive Mechanism Housing Mechanical Failure Evaluation	453
3.9.4.3.1	Housing Description	453
3.9.4.3.2	Effects of Rod Travel Housing Longitudinal Failures	453
3.9.4.3.3	Effect of Rod Travel Housing Circumferential Failures	453
3.9.4.3.4	Summary	454
3.9.5	REACTOR PRESSURE VESSEL INTERNALS	454
3.9.5.1	Design Arrangements	454
3.9.5.1.1	Lower Core Support Structure	454

3.9.5.1.1.1	Support Structure Assembly	454
3.9.5.1.1.2	Lower Core Plate	454
3.9.5.1.1.3	Thermal Shield	455
3.9.5.1.1.4	Coolant Flow Passages	456
3.9.5.1.1.5	Support and Alignment Arrangements	456
3.9.5.1.2	Upper Core Support Assembly	456
3.9.5.1.3	In-Core Instrumentation Support Structures	457
3.9.5.2	Loading Conditions	458
3.9.5.3	Design Bases	458
3.9.6	INSERVICE INSPECTION OF PUMPS AND VALVES	459
3.9.6.1	General	459
3.9.6.2	Inservice Testing of Pumps	459
3.9.6.3	Inservice Testing of Valves	460
3.9.7	Extended Power Uprate (EPU)	460
Table 3.9-1	ORIGINAL DESIGN LOADING COMBINATIONS AND STRESS LIMITS	464
Table 3.9-2	RESIDUAL HEAT REMOVAL LOOP A STRESS SUMMARY	465
Table 3.9-3	MAIN STEAM LINE-LOOP B STRESS SUMMARY	466
Table 3.9-4	CHARGING LINE STRESS SUMMARY	467
Table 3.9-5	LOAD COMBINATIONS AND ACCEPTANCE CRITERIA FOR PRESSURIZER SAFETY AND RELIEF VALVE PIPING AND SUPPORTS - UPSTREAM OF VALVES	468
Table 3.9-6	LOAD COMBINATIONS AND ACCEPTANCE CRITERIA FOR PRESSURIZER SAFETY AND RELIEF VALVE PIPING AND SUPPORTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION	469
Table 3.9-7	DEFINITIONS OF LOAD ABBREVIATIONS	470
Table 3.9-8	LOADING COMBINATIONS AND STRESS LIMITS FOR PIPING FOR SEISMIC UPGRADE PROGRAMS	471
Table 3.9-9	ALLOWABLE STEAM GENERATOR NOZZLE LOADS	472
Table 3.9-10	REACTOR COOLANT PUMP AUXILIARY NOZZLE UMBRELLA LOADS	473
Table 3.9-11	SYSTEMATIC EVALUATION PROGRAM STRUCTURAL BEHAVIOR CRITERIA FOR DETERMINING SEISMIC DESIGN ADEQUACY	476
Table 3.9-12	MECHANICAL COMPONENTS SELECTED FOR SEP SEISMIC REVIEW	477
Table 3.9-13	MAXIMUM STRESS HOT-LEG BREAK (ORIGINAL ANALYSIS)	478
Table 3.9-14	MAXIMUM STRESS COLD-LEG BREAK (ORIGINAL ANALYSIS)	479

Table 3.9-15	MAXIMUM CORE BARREL STRESS AND DEFLECTION UNDER HOT-LEG BLOWDOWN (ORIGINAL ANALYSIS)	480
Table 3.9-16a	MAXIMUM STRESS INTENSITIES AND DEFLECTION COLD-LEG BLOWDOWN (ORIGINAL ANALYSIS) - IN THE UPPER BARREL	481
Table 3.9-16b	MAXIMUM STRESS INTENSITIES AND DEFLECTION COLD-LEG BLOWDOWN (ORIGINAL ANALYSIS) - AT THE UPPER BARREL ENDS	482
Table 3.9-17	CORE BARREL STRESSES (ORIGINAL ANALYSIS)	483
Table 3.9-18	CORE BARREL STRESSES (ORIGINAL ANALYSIS)	484
Table 3.9-19	CORE BARREL STRESSES (ORIGINAL ANALYSIS)	485
Table 3.9-20	CORE BARREL STRESSES (ORIGINAL ANALYSIS)	486
Table 3.9-21	CORE BARREL STRESSES (ORIGINAL ANALYSIS)	487
Table 3.9-22	CORE BARREL STRESSES (ORIGINAL ANALYSIS)	489
Table 3.9-23a	LOAD COMBINATIONS AND ALLOWABLE STRESS LIMITS FOR PRIMARY EQUIPMENT SUPPORTS EVALUATION - FOR PLANT EVENTS	490
Table 3.9-23b	LOAD COMBINATIONS AND ALLOWABLE STRESS LIMITS FOR PRIMARY EQUIPMENT SUPPORTS EVALUATION - DEFINITION OF LOADING CONDITIONS FOR PRIMARY EQUIPMENT SUPPORTS EVALUATION IN TABLE 3.9-23a	491
Table 3.9-24	RESIDUAL HEAT REMOVAL LOOP A SUPPORT LOADS ¹ CALCULATED FOR IE BULLETIN 79-07	492
Table 3.9-25a	MAIN STEAM LINE LOOP B SUPPORT LOADS ² CALCULATED FOR IE BULLETIN 79-07 - SEISMIC SUPPORT	495
Table 3.9-25b	MAIN STEAM LINE LOOP B NOZZLE LOADS CALCULATED FOR IE BULLETIN 79-07 - NOZZLE LOADS	496
Table 3.9-26	CHARGING LINE SUPPORT LOADS ^a CALCULATED FOR IE BULLETIN 79-07	497

Table 3.9-27	LOADING COMBINATIONS AND STRESS LIMITS FOR SUPPORTS ON PIPING SYSTEMS	502
Table 3.9-28	ANALYSIS OF TYPICAL PIPE SUPPORT BASE PLATES CALCULATED FOR IE BULLETIN 79-02	503
Table 3.9-29	INTERNALS DEFLECTIONS UNDER ABNORMAL OPERATION	504
3.10	SEISMIC QUALIFICATION OF SEISMIC CATEGORY I INSTRUMENTATION AND ELECTRICAL EQUIPMENT	505
3.10.1	SEISMIC QUALIFICATION CRITERIA	505
3.10.1.1	Original Criteria	505
3.10.1.2	Current Criteria	505
3.10.2	SEISMIC QUALIFICATION OF ELECTRICAL EQUIPMENT AND INSTRUMENTATION	506
3.10.2.1	Introduction	506
3.10.2.2	Battery Racks	507
3.10.2.3	Motor Control Centers 1L and 1M	507
3.10.2.4	Switchgear	508
3.10.2.5	Control Room Electrical Panels	508
3.10.2.6	Electrical Cable Raceways	509
3.10.2.7	Constant Voltage Transformers	509
3.10.3	SEISMIC QUALIFICATION OF SUPPORTS OF ELECTRICAL EQUIPMENT AND INSTRUMENTATION	509
3.10.3.1	Equipment Addressed	510
3.10.3.2	Raceway Anchorages	510
3.10.3.2.1	Test Program	510
3.10.3.2.2	Test Loads	511
3.10.3.2.3	Expansion Anchor Test Results	512
3.10.3.2.4	Frictional Anchor Test Results	512
3.10.3.2.5	Embedded Anchor Test Results	513
3.10.3.3	Class 1E Equipment Anchorage Qualification Program	513
3.10.3.4	Conclusions	514
3.10.4	FUNCTIONAL CAPABILITY OF COMPONENTS	514
3.10.5	SEISMIC CATEGORY I TUBING	514
3.10.5.1	Codes and Standards	514
3.10.5.1.1	Tubing Design Requirements	515
3.10.5.1.2	Tubing Supports Design Requirements	515

3.10.5.2	Load Conditions	516
3.10.5.2.1	Tubing	516
3.10.5.2.2	Tubing Supports	516
3.10.5.3	Routing Requirements	517
Table 3.10-1	MAJOR CLASS 1E COMPONENTS AND THE BASIS FOR SEISMIC QUALIFICATION	520
Table 3.10-2	ELECTRICAL COMPONENTS SELECTED FOR SEISMIC REVIEW	522
Table 3.10-3	SHELL ANCHOR TEST SUMMARY	523
Table 3.10-4	FRICTION BOLT TEST RESULT SUMMARY	524
Table 3.10-5	CATEGORY 3 ANCHORS TEST SUMMARY	525
Table 3.10-6	STRESS LIMITS FOR TUBING	526
3.11	ENVIRONMENTAL DESIGN OF MECHANICAL AND ELECTRICAL EQUIPMENT	527
3.11.1	BACKGROUND	527
3.11.1.1	Initial Design Considerations	527
3.11.1.2	Review of Environmental Qualification of Safety-Related Electrical Equipment	527
3.11.2	Equipment Identification	528
3.11.3	IDENTIFICATION OF LIMITING ENVIRONMENTAL CONDITIONS	528
3.11.3.1	Inside Containment	528
3.11.3.1.1	Post Loss-of-Coolant Accident Environment	528
3.11.3.1.2	Post Main Steam Line Break Environment	530
3.11.3.2	Auxiliary Building	530
3.11.3.2.1	Heating, Ventilation, and Air Conditioning	530
3.11.3.2.2	Loss of Ventilation	531
3.11.3.2.3	Radiation Levels	532
3.11.3.2.4	Flooding	532
3.11.3.3	Intermediate Building	532
3.11.3.4	Cable Tunnel	533
3.11.3.5	Control Building	533
3.11.3.6	Diesel Generator Rooms	534
3.11.3.7	Turbine Building	534
3.11.3.8	Auxiliary Building Annex	535
3.11.3.9	Screen House	535
3.11.4	EQUIPMENT QUALIFICATION INFORMATION	535
3.11.5	ENVIRONMENTAL QUALIFICATION PROGRAM	535

Table 3.11-1	ENVIRONMENTAL SERVICE CONDITIONS FOR EQUIPMENT DESIGNED TO MITIGATE DESIGN-BASIS EVENTS	540
Table 3.11-2	ESTIMATES FOR TOTAL AIRBORNE GAMMA DOSE CONTRIBUTORS IN CONTAINMENT TO A POINT IN THE CONTAINMENT CENTER - GINNA STATION	549
Table 3.11-3	ESTIMATES FOR TOTAL AIRBORNE BETA DOSE CONTRIBUTORS IN CONTAINMENT TO A POINT IN THE CONTAINMENT CENTER - GINNA STATION	551
Table 3.11-4	ESTIMATES FOR TOTAL AIRBORNE GAMMA DOSE CONTRIBUTORS IN CONTAINMENT TO A POINT IN THE CONTAINMENT CENTER, REGULATORY GUIDE 1.89, REVISION 1	553
Table 3.11-5	ESTIMATES FOR TOTAL AIRBORNE BETA DOSE CONTRIBUTORS IN CONTAINMENT TO A POINT IN THE CONTAINMENT CENTER, REGULATORY GUIDE 1.89, REVISION 1	555
Table 3.11-6	GINNA STATION/REGULATORY GUIDE 1.89, APPENDIX D, COMPARISON OF POSTACCIDENT RADIATION ENVIRONMENT ASSUMPTIONS	557

FIGURES

Figure 3.7-1	Seismic Response Spectra, 8%g Housner Model
Figure 3.7-2	Seismic Response Spectra, 20%g Housner Model
Figure 3.7-3	NRC Systematic Evaluation Program Site Specific Spectrum, Ginna Site (5% Damping)
Figure 3.7-4	Comparison of the Housner Response Spectrum for 2% of Critical Damping with the 7% Regulatory Guide 1.60 Spectrum
Figure 3.7-5	In-Structure Response Spectra for Interconnected Building, Half-Area and Full-Area Models
Figure 3.7-6	Containment Building and Complex of Interconnected Seismic Category I and Nonseismic Structures, Plan View
Figure 3.7-7	Horizontal Response Spectra - SEP Systematic Evaluation Program
Figure 3.7-8	Steam Generator Mathematical Model
Figure 3.7-9	Mathematical Model of Reactor Vessel
Figure 3.7-10	Seismic Average Acceleration Spectrum Design Earthquake, 1% Damping
Figure 3.7-11	Locations Where In-Structure Response Spectra Were Generated in Interconnected Building Complex
Figure 3.7-12	SEP Response Spectra for Pressurizer PR-1 (Containment Building Elevation 253 ft) for 3%, 5%, and 7% Damping
Figure 3.7-13	SEP Response Spectra for Control Rod Drive (Containment Building Elevation 253 ft) for 3%, 5%, 7% Damping
Figure 3.7-14	SEP Response Spectra for Control Rod Drive (Containment Building Elevation 278 ft) for 3%, 5%, and 7% Damping

Figure 3.7-15	SEP Response Spectra for Steam Generator SG-1A (Containment Building Elevation 250 ft) for 3%, 5%, and 7% Damping
Figure 3.7-16	SEP Response Spectra for Steam Generator SG-1A (Containment Building Elevation 278 ft) for 3%, 5%, and 7% Damping
Figure 3.7-17	SEP Response Spectra for Steam Generator SG-1B (Containment Building Elevation 250 ft) for 3%, 5%, and 7% Damping
Figure 3.7-18	SEP Response Spectra for Steam Generator SG-1B (Containment Building Elevation 278 ft) for 3%, 5%, and 7% Damping
Figure 3.7-19	SEP Response Spectra for Reactor Coolant Pump Rp-1A (Containment Building Elevation 247 ft) for 3%, 5%, and 7% Damping
Figure 3.7-20	SEP Response Spectra for Reactor Coolant Pump RP-1B (Containment Building Elevation 247 ft) for 3%, 5%, and 7% Damping
Figure 3.7-21	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Auxiliary Building Platform (Elevation 281 ft 6 in)
Figure 3.7-22	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Auxiliary Building Heat Exchanger 35 (Elevation 281 ft 6 in)
Figure 3.7-23	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Auxiliary Building Surge Tank 34
Figure 3.7-24	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Auxiliary Building Boric Acid Storage Tank 34
Figure 3.7-25	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Auxiliary Building Operating Floor (Elevation 271 ft 6 in)
Figure 3.7-26	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Control Building Basement Floor (Elevation 250 ft 0 in)
Figure 3.7-27	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Control Building Relay Room Floor (Elevation 269 ft 9 in)
Figure 3.7-28	SEP Equipment Response Spectra for 3%, 5%, and 7% Damping at Control Room Floor (Elevation 289 ft 9 in)
Figure 3.7-29	Residual Heat Removal Line Inside Containment
Figure 3.7-30	Lumped Mass Model - Steam Line B
Figure 3.7-31	Structural Model, Pressurizer Safety and Relief Line
Figure 3.8-1	Containment Cross Section and Details
Figure 3.8-2	Containment Mat Foundation and Ring Girder
Figure 3.8-3	Containment Mat Foundation, Reinforcement and Details
Figure 3.8-4	Containment Wall Reinforcement and Details
Figure 3.8-5	Containment Dome Reinforcement and Details
Figure 3.8-6	Containment Miscellaneous Embedded Back-Up Steel
Figure 3.8-7	Tendon Vent Cans and Grease Fill Connections
Figure 3.8-8	Temperature Gradients - Operating Conditions
Figure 3.8-9	Earthquake Meridional Forces

Figure 3.8-10	Containment Dynamic Analysis Model
Figure 3.8-11	Ginna Containment Mode Shapes
Figure 3.8-12	Ginna Containment - Earthquake Response
Figure 3.8-13	Moments, Shears, Deflection, Tensile Force, and Hoop Tension Diagrams Load Combination A
Figure 3.8-14	Moments, Shears, Deflection, Tensile Force, and Hoop Tension Diagrams Load Combination B
Figure 3.8-15	Moments, Shears, Deflection, Tensile Force, and Hoop Tension Diagrams Load Combination C
Figure 3.8-16	Tendon to Rock Coupling
Figure 3.8-17	Containment - Top Tendon Access
Figure 3.8-18	Containment Miscellaneous Steel Tendon Conduit - Hinge Detail
Figure 3.8-19	Liner Knuckle Dimensions
Figure 3.8-20	Containment Base to Cylinder Model
Figure 3.8-21	Containment Dome to Cylinder Discontinuity Model
Figure 3.8-22	Cracked Wall Shear Modulus Analysis
Figure 3.8-23	Liner Shear Stress Analysis
Figure 3.8-24	Windgirder, Shear Channels, and Shear Studs
Figure 3.8-25	Cylinder Liner Plate Support Model
Figure 3.8-26	Containment Penetration Details
Figure 3.8-27	Containment Penetration Details (Typical)
Figure 3.8-28	Composite Drawing Electrical Penetration
Figure 3.8-29	Containment Penetrations Section and Details
Figure 3.8-30	Containment Equipment Hatch
Figure 3.8-31	Containment Personnel Hatch
Figure 3.8-32	Containment - Fuel Transfer Tube Penetration
Figure 3.8-33	Containment Penetrations Arrangements and Location
Figure 3.8-34	Test Coupon - Containment Concrete Shell
Figure 3.8-35	Cadweld Splice Test Results
Figure 3.8-36	Quality Control Chart for 5000 PSI Concrete
Figure 3.8-37	Neoprene Base Hinge Load Deformation Specimen 1
Figure 3.8-38	Neoprene Base Hinge Load Deformation Specimen 2
Figure 3.8-39	Rock Anchor Test A-1
Figure 3.8-40	Containment - Rock Anchor A Test
Figure 3.8-41	Containment - Rock Anchor B Test
Figure 3.8-42	Containment - Rock Anchor C Test

Figure 3.8-43	Accident Temperature Transient Inside the Containment Used for Liner Analysis
Figure 3.8-44	Accident Pressure Transient Inside the Containment Used for Liner Analysis
Figure 3.8-45	Plan View of the Facade Structure and Containment
Figure 3.8-46	Accident Temperature Gradient Through the Uninsulated Containment Shell After 94 Seconds
Figure 3.8-47	Accident Temperature Gradient Through the Uninsulated Containment Shell After 380 Seconds
Figure 3.8-48	Ginna Containment Structure
Figure 3.8-49	Liner Stud Interaction Models
Figure 3.8-50	Accident Temperature Distribution in the Steel Liner
Figure 3.8-51	Force Displacement Curve for 3/4 in. Headed Studs
Figure 3.8-52	Force Displacement Curve for 5/8 in. S6L Studs
Figure 3.8-53	Strut Buckling Under P and Delta T
Figure 3.8-54	Pressure Effect on Liner Buckling Comparison With LOCA
Figure 3.8-55	Reactor Containment Internal Structures
Figure 3.8-56	Containment Interior Structures Model for STARDYNE
Figure 3.8-57	Schematic Plan View of Major Ginna Structures
Figure 3.8-58	Three-Dimensional View of Interconnected Building Complex
Figure 3.8-59	Flow Chart of the Analysis of the Interconnected Building Complex
Figure 3.8-60	Masonry Wall Reevaluation, Wall Location Plan, Lower Levels
Figure 3.8-61	Masonry Wall Reevaluation, Wall Location Plan, Intermediate Levels
Figure 3.8-62	Masonry Wall Reevaluation, Wall Location Plan, Operating Levels
Figure 3.9-1	Steam-Generator Water Hammer Preliminary Forcing Function
Figure 3.9-2	Plastic Model of Reactor Coolant System - Plan View
Figure 3.9-3	Lumped Mass Dynamic Model of PCV 434
Figure 3.9-4	Lumped Mass Dynamic Model of PCV 435
Figure 3.9-5	Comparison of WHAM Results With LOFT Semi-Scale Blowdown Experiments, Test No. 519
Figure 3.9-6	Comparison of WHAM Results With LOFT Semi-Scale Blowdown Experiments, Test No. 560
Figure 3.9-6a	Steam Generator Upper Support Systems
Figure 3.9-7	Control Rod Drive Mechanism Assembly
Figure 3.9-8	Control Rod Drive Mechanism Schematic
Figure 3.9-9	Reactor Vessel Internals
Figure 3.9-10	Detailed View of Reactor Vessel Internals

Figure 3.10-1	Q-Deck Detail	
Figure 3.10-2	Unistrut Detail	
Figure 3.10-3	Threaded Insert Detail Poured in Place Anchor	
Figure 3.10-4	Tray Support Types for Friction Bolt Testing	
Figure 3.11-1	Containment Volume and Reactor Power LOCA Dose Corrections	
Appendix 3A	INITIAL EVALUATION OF CAPABILITY TO WITHSTAND TOR-NADOES	558
3A.1	INTRODUCTION AND CONCLUSIONS	559
3A.2	IDENTIFICATION OF CRITICAL SYSTEMS AND STRUCTURES	561
3A.3	TORNADO EFFECTS ON STRUCTURES	562
3A.3.1	GENERAL	562
3A.3.2	REACTOR CONTAINMENT	562
3A.3.3	AUXILIARY BUILDING	562
3A.3.4	INTERMEDIATE BUILDING	563
3A.3.5	DIESEL-GENERATOR ANNEX	563
3A.3.6	SCREEN HOUSE	563
3A.3.7	CONTROL ROOM	564
3A.3.8	SERVICE BUILDING	564
3A.3.9	CABLE TUNNELS	564
3A.4	TORNADO EFFECTS ON THE SYSTEMS REQUIRED FOR HOT SHUTDOWN	565
3A.4.1	DECAY HEAT REMOVAL	565
3A.4.1.1	Steam Relief System	565
3A.4.1.2	Auxiliary Feedwater System	565
3A.4.1.3	Service Water System	566
3A.4.2	REACTIVITY CONTROL	567
3A.4.2.1	Boration System	567
3A.4.2.2	Boration Using Refueling Water	567
3A.4.3	CONTAINMENT VENTILATION SYSTEM	568
3A.4.4	EMERGENCY POWER SUPPLY SYSTEM	569
3A.4.5	CONTROL SYSTEM	569
3A.4.5.1	Control Room	569
3A.4.5.2	Systems of Batteries	569
3A.4.5.3	Steam-Generator Level and Pressure Indicators, Pressurizer Pressure and Level Control	569
3A.5	TORNADO EFFECT ON SPENT FUEL POOL	571
	<u>Appendix 3A Figures</u>	

Figure 1	Boration System	
Figure 2	Site Plot Plan	
Figure 3	Diesel Generator Annex - Elevation 253 ft 6 in.	
Figure 4	Screen House Layout	
Figure 5	Steam Relief Valves	
Figure 6	Auxiliary Feedwater Pumps	
Figure 7	Component Cooling System	
Figure 8	Spent Fuel Storage Pool, Plan View	
Figure 9	Spent Fuel Storage Pool, Section View	
Appendix 3B	DESIGN OF LARGE OPENING REINFORCEMENTS FOR CON- TAINMENT VESSEL	572
Table of Contents		573
Summary		576
I.	Design Bases	576
II.	GENERAL DESCRIPTION	576
III.	STRESS DISTRIBUTION AROUND A CIRCULAR HOLE IN A CIRCULAR CYLINDRICAL SHELL	576
IV.	ANALYSIS OF STRESSES AROUND LARGE OPENINGS	576
V.	VERIFICATION OF REINFORCEMENT ADEQUACY	577
1.	DESIGN BASES	579
1.1	General	579
1.2	Design Loads	579
1.3	Load Combinations	579
1.4	Material Stress/Strain Criteria	580
1.5	Test Condition	582
1.6	Operating Condition	582
2.	GENERAL DESCRIPTION OF OPENING REINFORCEMENT	583
2.1	Introduction	583
2.2	Rebar for Discontinuity Stresses	583
2.3	Normal Shear at Edge of Opening	583
2.4	Prestressing	583
3.	STRESS DISTRIBUTION AROUND A CIRCULAR HOLE IN A CIRCULAR CYLINDRICAL SHELL	584
3.1	Introduction	584
3.2	Finite Element Method	585
3.3	Applications of Three-Dimensional Photoelasticity	586

4.	ANALYSIS OF THE STRESSES AROUND LARGE OPENINGS IN THE R. E. GINNA SECONDARY CONTAINMENT VESSEL	588
4.1	Verification of Finite-element Method of Analysis	588
4.2	General Considerations Concerning Methods of Analysis of Reinforced Concrete Structures in the Cracked Condition	589
4.3	Stress Analysis in Cracked and Uncracked Conditions Under Operating and Accident Loads	590
4.3.2	Basic Loading Conditions	592
4.3.3	Effect of Concrete Cracking	595
4.3.4	Effect of Creep and Shrinkage	597
5.	Verification of Design Criteria	598
5.1	Basis For Verification of Shell Loading Capacity Due to Primary Loads (Principal Stress-resultants and Principal Stress-couples)	598
5.2	Interaction Diagram	599
5.3	Reinforcing Steel	600
5.4	Maximum Liner Stresses	600
5.5	Penetration Barrel	600
5.6	Normal Shear	601
5.7	Rebar Anchorage	602
5.8	Tendon Losses	603
5.9	Summary of Design and Conclusions	604
Table 4-1	Load Combinations	608
Table 4-2	Stress Around Equipment Hatch-Loading (Uncracked Shell)	609
Table 4-3	Stress Around Equipment Hatch-Loading (Cracked Shell)	611
Table 5-1	Maximum Liner Stresses Stress tangent to the edge in Ksi	619
Appendix A to APPENDIX 3B	EFFECT OF CONCRETE CREEP AND THE SUSTAINED OPERATING STRESSES ON STRESS DISTRIBUTION AROUND OPENINGS IN A RAPIDLY PRESSURIZED REINFORCED CONCRETE VESSEL	620
3B.A	EFFECT OF CONCRETE CREEP AND THE SUSTAINED OPERATING STRESSES ON STRESS DISTRIBUTION AROUND OPENINGS IN A RAPIDLY PRESSURIZED REINFORCED CONCRETE VESSEL	621
Appendix B TO APPENDIX 3B	EARTHQUAKE ANALYSIS	628
3B.B	Earthquake Analysis	629
ADDENDUM TO APPENDIX 3B	ADDENDUM TO THE REPORT ON: DESIGN OF LARGE OPENING REINFORCEMENTS FOR CONTAINMENT VESSEL	630
3B.C	Introduction	631
1	Design	632

1.1	Concrete Shear	632
1.2	Interaction Diagrams	632
1.3	Earthquake Design	632
1.4	Thermal Gradients	632
1.5	Penetration Material	633
1.6	Working Strength Design	633
1.7	Anchorage Plate Bearing Stress	633
1.8	Insulated Liner Temperature Increase	633
1.9	High Strength Rebar	633
1.10	Proof Test Instrumentation	633
1.11	Operating Conditions	634
1.12	Shear - Diagonal Tension	634
1.13	Normal Shears	635
1.14	Radial Shear at the Periphery of the Opening	635
1.15	Accident Temperature Effects	635
1.16	Analytical Model for Different Load Combinations	635
1.17	Shear Reinforcement	635
1.18	Equation (5.11)	636
1.19	Rebar Located Away from the Barrel	636
1.20	Verification of Analysis	637
1.21	Test Problem	638
1.22	Accident Temperature	638
2	Construction	639
2.1	Construction Schedule	639
2.2	Concrete Removal	639
2.3	Concrete Work	639
2.4	Retensioning Tendons	640
2.5	Rebar Splices	640
2.6	Tendon Conduit	640
Table I	STRESS AROUND EQUIPMENT HATCH LOADING CONDITION NO. 4 - Accident Temperature	641
	<u>Appendix 3B Figures</u>	
Figures	Appendix 3B Figures	
Figure 1		
Figure 2		
Figure 3	Stress Distribution Around Openings in Cylindrical Shells	

Figure 4	Grid for Finite Element Analysis of the Stresses Around Openings
Figure 5	Membrane Stress Around Opening Edge (Vessel Subject to Internal Pressure)
Figure 6	Surface Stresses Around Opening Edge (Vessel Subject to Internal Pressure)
Figure 7	Hoop Stresses Along Longitudinal Axis (Vessel Subject to Internal Pressure)
Figure 8	Axial Stresses Along Transverse Axis (vessel Subject to Internal Pressure)
Figure 9	Hoop Stress-Resultant No Along Symmetry Axes (Test Problem)
Figure 10	Layer Thickness And Destination
Figure 11	Nodal Forces Due to Curvature of Tendons in the Neighborhood of Opening
Figure 12	Stress Distribution Around Openings (Thermal Gradient Near Equipment Opening)
Figure 13	Steady State Temperature Distributions - Winter Gradient
Figure 14	Stress Distribution Around Openings (Effect of Bond Failure Along Terminated Rebars)
Figure 15	Hoop Stress-Resultant Along Horizontal And Vertical Symmetry Axes (Internal Pressure = 69 PSI)
Figure 16	Shell Displacements (Final Vertical Prestress)
Figure 17	Shell Displacements (69 PSI Internal Pressure)
Figure 18	Interaction Diagram for Axial Compression/Tension and Bending
Figure 19	Interaction Diagram Ring Steel Direction Elements No. 73 & 74
Figure 20	Interaction Diagram Elements No. 97, 100, & 101
Figure 21	Interaction Diagram Elements No. 97, 100, & 101
Figure 22	Interaction Diagram Elements No. 33, 55, 66, & 77
Figure 23	Interaction Diagram Element No. 77
Figure 24	Interaction Diagram Element No. 55
Drawings	
Figure Drawing 1	Reactor Containment Vessel - Equipment/Personnel Access Reinforcement - Enlarged Sections
Figure Drawing 2	Reactor Containment Vessel - Equipment Access Opening Reinforcement - Stretch-out & Sections
Figure I	Comparison of H.H. & GAI Results Hoop Stress Resultants Along Horizontal and Vertical Symmetry Axes (Internal Pressure = 69 PSI)
Figure Drawing 1	Reactor Containment Vessel - Equipment/Personnel Access Reinforcement - Enlarged Sections

Figure Drawing 2	Reactor Containment Vessel - Equipment Access Opening Reinforcement - Stretch-out & Sections	
Figure Drawing 3	Large Openings - Pour Schedule	
Appendix 3C	CONTAINMENT SHELL STRESS CALCULATION RESULTS	642
Table 3C-1	CONTAINMENT SHELL STRESS CALCULATION RESULTS	643
Appendix 3D	CONTAINMENT TENDON ANCHORAGE HARDWARE CAPACITY TESTS	668
	Compressive Load Tests of 90 Wire Tendon Base Plate - Test on Concrete Stand	669
	Compressive Load Tests of 90 Wire Tendon Base Plate - Test on Concrete Stand	673
	Compression Tests of 90-Wire Anchor Head Assembly	681
	Compression Tests of 90-Wire Anchor Head Assembly	683
	Load Tests of Coupler and Adaptor 90-11	690
	Load Tests of Coupler and Adaptor 90-11	692
	90 Wire Tendon Test	696
	90 Wire Tendon Test	697
	90 Wire Tendon Test	698
	Load Tests of 90-X7 Coupler	702
Appendix 3E	CONTAINMENT LINER INSULATION PREOPERATIONAL TESTS	704
	BM Containment Insulation SP-5290 Ginna Plant	705
	Report No. E455-T-268, VINYLCEL (4 pcf) - Water Vapor Permeability and Humid Aging Tests	707
	Report No. E455-T-266, VINYLCEL (4 pcf) - Effect of Heat and Pressure	711
	Report No. E455-T-258, VINYLCEL - Resistance to Flame Exposure	718
Appendix 3F	SUMMARY OF STRUCTURAL DESIGN CODE COMPARISON	740
Table of Contents		741
3F.1	INTRODUCTION	742
Table 3F.2-1	AISC 1963 VERSUS AISC 1980 SUMMARY OF CODE COMPARISON	743
Table 3F.3-1	ACI 318-63 VERSUS ACI 349-76 SUMMARY OF CODE COMPARISON	747
Table 3F.4-1	ACI 301-63 VERSUS ACI 301-72 (REVISED 1975) SUMMARY OF CODE COMPARISON	756
Table 3F.5-1	ACI 318-63 VERSUS ASME B&PV CODE, SECTION III, DIVISION 2, 1980, SUMMARY OF CODE COMPARISON	762