

<u>5</u>	<u>REACTOR COOLANT SYSTEM AND CONNECTED SYSTEMS</u>	<u>1</u>
5.1	SUMMARY DESCRIPTION	2
5.1.1	GENERAL	2
5.1.2	PERFORMANCE OBJECTIVES	2
5.1.3	DESIGN CRITERIA	2
5.1.3.1	Quality Standards	3
5.1.3.2	Performance Standards	3
5.1.3.3	Records Requirements	4
5.1.3.4	Missile Protection	4
5.1.3.5	Reactor Coolant Pressure Boundary	4
5.1.3.6	Monitoring Reactor Coolant Leakage	5
5.1.3.7	Reactor Coolant Pressure Boundary Capability	6
5.1.3.8	Reactor Coolant Pressure Boundary Rapid Propagation Failure Prevention	6
5.1.3.9	Reactor Coolant Pressure Boundary Surveillance	7
5.1.3.10	Adequacy of Reactor Coolant System Design Relative to 1972 10 CFR 50, Appendix A, Criteria	8
5.1.4	DESIGN CHARACTERISTICS	8
5.1.4.1	Design Pressure	8
5.1.4.2	Design Temperature	9
5.1.5	CYCLIC LOADS	9
5.1.6	SERVICE LIFE	9
5.1.7	RELIANCE ON INTERCONNECTED SYSTEMS	10
5.1.8	SYSTEM INCIDENT POTENTIAL	10
Table 5.1-1	REACTOR COOLANT SYSTEM PRESSURE SETTINGS	12
Table 5.1-2	REACTOR COOLANT PIPING DESIGN DATA	13
Table 5.1-3	REACTOR COOLANT SYSTEM DESIGN PRESSURE DROP	14
Table 5.1-4	THERMAL AND LOADING CYCLES	15
5.2	INTEGRITY OF THE REACTOR COOLANT PRESSURE BOUNDARY	16
5.2.1	COMPLIANCE WITH CODES	16
5.2.1.1	System Integrity	16
5.2.1.2	Codes and Classifications	17
5.2.1.2.1	Code Requirements	17
5.2.1.2.2	Quality Control	17
5.2.1.2.3	Field Erection Procedures	18
5.2.1.3	Seismic Loads	18

5.2.2	OVERPRESSURIZATION PROTECTION	19
5.2.2.1	Normal Operation	19
5.2.2.2	Low Temperature Overpressure Protection (LTOP) System	19
5.2.2.2.1	Design Bases	20
5.2.2.2.2	System Description	20
5.2.2.2.3	System Evaluation	21
5.2.2.2.3.1	General	21
5.2.2.2.3.2	Mass Addition Case	22
5.2.2.2.3.3	Heat Addition at 60°F	22
5.2.2.2.3.4	Heat Addition at 320°F	23
5.2.2.2.3.5	Administrative Controls	23
5.2.2.2.4	Tests and Inspections	24
5.2.3	REACTOR COOLANT PRESSURE BOUNDARY MATERIALS	24
5.2.3.1	Material Specifications	24
5.2.3.1.1	Nondestructive Examination of Materials and Components Prior to Operation	24
5.2.3.1.1.1	Quality Assurance Program	24
5.2.3.1.1.2	Welding and Heat Treatment	25
5.2.3.1.2	Quality Assurance for Electroslag Welds	26
5.2.3.1.2.1	Piping Elbows	26
5.2.3.1.2.2	Reactor Coolant Pump Casings	26
5.2.3.1.2.3	Reactor Coolant Pump Field Erection and Welding	28
5.2.3.2	Compatibility With Reactor Coolant	28
5.2.4	INSERVICE INSPECTION AND TESTING OF THE REACTOR COOLANT SYSTEM PRESSURE BOUNDARY	29
5.2.4.1	Inservice Inspection Program	29
5.2.4.2	Inspection Areas and Components	29
5.2.4.2.1	Accessible Components and Areas	29
5.2.4.2.2	Accessible Areas During Refueling	31
5.2.4.3	Accessibility	31
5.2.4.4	Examination Methods	32
5.2.4.5	Evaluation of Examination Results	33
5.2.4.6	Repair Requirements	33
5.2.4.7	Pressure Testing	33
5.2.4.8	Exemptions	33

5.2.5	DETECTION OF LEAKAGE THROUGH REACTOR COOLANT PRESSURE BOUNDARY	34
5.2.5.1	Leakage Detection Methods	34
5.2.5.2	Leakage Limitations	35
5.2.5.3	Locating Leaks	36
5.2.5.4	Leakage Detection System Descriptions	36
5.2.5.4.1	Containment Air Particulate and Radiogas Monitor	36
5.2.5.4.1.1	Air Particulate Monitor	36
5.2.5.4.1.2	Sensitivity Assumptions	36
5.2.5.4.1.3	Leakage Detection Threshold	38
5.2.5.4.1.4	Radiogas Monitor	39
5.2.5.4.2	Humidity Detector	39
5.2.5.4.3	Condensate Measuring System	39
5.2.5.4.4	Liquid Inventory in Process Systems and Containment Sumps	40
5.2.5.5	Leakage Detection System Evaluation	40
Table 5.2-1	REACTOR COOLANT SYSTEM CODE REQUIREMENTS	43
Table 5.2-2	MATERIALS OF CONSTRUCTION OF THE REACTOR COOLANT SYSTEM COMPONENTS	44
Table 5.2-3	REACTOR COOLANT SYSTEM QUALITY ASSURANCE PROGRAM	45
Table 5.2-4	Table DELETED	48
Table 5.2-5	REACTOR COOLANT PRESSURE BOUNDARY TO CONTAINMENT LEAK-AGE DETECTION SYSTEMS	49
Table 5.2-6	REACTOR COOLANT PRESSURE BOUNDARY INTERSYSTEM LEAKAGE DETECTION SYSTEMS	50
Table 5.2-7	SEQUENCE OF EVENTS - MASS ADDITION CASE	51
Table 5.2-8	HEAT ADDITION AT 60°F - SEQUENCE OF EVENTS	52
Table 5.2-9	HEAT ADDITION AT 320°F - SEQUENCE OF EVENTS	53
5.3	REACTOR VESSEL	54
5.3.1	REACTOR VESSEL MATERIALS	54
5.3.1.1	Reactor Vessel Description	54
5.3.1.2	Material Specifications	55
5.3.1.3	Testing and Surveillance	56
5.3.2	PRESSURE-TEMPERATURE LIMITS	56

5.3.2.1	Thermal and Pressure Loadings	56
5.3.2.2	Pressure-Temperature Limits	57
5.3.2.3	Pressure-Temperature Limit Calculation	58
5.3.2.4	Irradiation Effect on Pressure-Temperature Limit	58
5.3.2.5	Heatup and Cooldown Rates	59
5.3.3	REACTOR VESSEL INTEGRITY	59
5.3.3.1	Safety Factors	59
5.3.3.2	Material Surveillance Program	61
5.3.3.3	Surveillance Program Analysis	62
5.3.3.3.1	Results Summary	63
5.3.3.3.2	Charpy V-Notch Impact Test Results	65
5.3.3.3.3	Tension Test Results	66
5.3.3.3.4	Radiation Analysis and Neutron Dosimetry	66
5.3.3.4	Analysis of Effects of Loss of Coolant and Safety Injection on the Reactor Vessel	66
5.3.3.4.1	Reactor Vessel	66
5.3.3.4.2	Safety Injection Nozzles	68
5.3.3.4.3	Fuel Assembly Grid Springs	68
5.3.3.4.4	Core Barrel and Thermal Shield	68
5.3.3.4.5	Subsequent Analyses of Reactor Vessel	68
5.3.3.5	Pressurized Thermal Shock	69
Table 5.3-1	REACTOR VESSEL SPECIFICATIONS	74
Table 5.3-2	REACTOR VESSEL DESIGN DATA	75
Table 5.3-3	REACTOR VESSEL MATERIALS	76
Table 5.3-4	IDENTIFICATION OF BELTLINE MATERIALS	77
Table 5.3-5	BELTLINE MATERIAL CHEMICAL COMPOSITION (WEIGHT PERCENT)	78
Table 5.3-6a	MECHANICAL PROPERTIES OF BELTLINE MATERIALS - FORGINGS	79
Table 5.3-6b	MECHANICAL PROPERTIES OF BELTLINE MATERIALS	80
Table 5.3-7	SUMMARY OF PRIMARY-PLUS-SECONDARY STRESS INTENSITY FOR COMPONENTS OF THE REACTOR VESSEL	81
Table 5.3-8	SUMMARY OF CUMULATIVE FATIGUE USAGE FACTORS FOR COMPONENTS OF THE REACTOR VESSEL	83
Table 5.3-9	SUMMARY OF SURVEILLANCE CAPSULE RESULTS	84
Table 5.3-10	COMPARISON OF SURVEILLANCE MATERIAL 30 FT-LB TRANSITION TEMPERATURE SHIFTS AND UPPER SHELF ENERGY DECREASES WITH REGULATORY GUIDE 1.99, REVISION 2, PREDICTIONS	85

5.4	COMPONENT AND SUBSYSTEM DESIGN	87
5.4.1	REACTOR COOLANT PUMPS	87
5.4.1.1	General Description	87
5.4.1.1.1	Centrifugal Pump	87
5.4.1.1.2	Controlled Leakage Shaft Seal	87
5.4.1.1.3	Pump Motor	88
5.4.1.1.4	Vibration Measurement	89
5.4.1.1.5	Lube Oil Leakage Collection System	89
5.4.1.2	Pump Flywheel Integrity	89
5.4.1.2.1	Pump Overspeed	89
5.4.1.2.2	Pump Flywheel Design and Fabrication	90
5.4.1.2.3	Flywheel Design Evaluation	90
5.4.1.2.4	Pump Seismic Design	91
5.4.1.2.5	Inservice Inspection Program	91
5.4.1.2.6	Conclusion	91
5.4.2	STEAM GENERATORS	91
5.4.2.1	Replacement Steam Generator Materials	92
5.4.2.2	Steam Generator Inservice Inspection	92
5.4.2.3	Replacement Steam Generator Design Evaluation	92
5.4.2.4	High Cycle Fatigue Failure of Original Steam Generator Tubes	93
5.4.3	REACTOR COOLANT PIPING	93
5.4.3.1	General	93
5.4.3.1.1	General Description	93
5.4.3.1.2	Pressure Isolation of Low-Pressure Systems	94
5.4.3.2	Reactor Coolant System Vents	94
5.4.3.2.1	General	94
5.4.3.2.2	Reactor Head Vent System Description	95
5.4.4	MAIN STEAM LINE ISOLATION SYSTEM	96
5.4.5	RESIDUAL HEAT REMOVAL (RHR) SYSTEM	97
5.4.5.1	Design Bases	97
5.4.5.2	System Design	98
5.4.5.2.1	Codes and Classifications	99
5.4.5.2.2	Components	99

5.4.5.2.2.1	Heat Exchangers	99
5.4.5.2.2.2	Pumps	99
5.4.5.2.2.3	Valves	99
5.4.5.2.2.4	Piping	100
5.4.5.3	Performance Evaluation	100
5.4.5.3.1	Isolation Requirement	100
5.4.5.3.1.1	Isolation Valve Description	100
5.4.5.3.1.2	Deviations From Branch Technical Position RSB 5-1	101
5.4.5.3.2	Residual Heat Removal Overpressure Protection	102
5.4.5.3.2.1	Design Basis	102
5.4.5.3.2.2	Analysis	102
5.4.5.3.2.3	Effect of Stuck Open Relief Valve	103
5.4.5.3.3	Residual Heat Removal Pump Protection	104
5.4.5.3.4	Single-Failure Considerations	105
5.4.5.3.5	Leakage Provisions	106
5.4.5.3.6	Boron Concentration	107
5.4.5.4	Residual Heat Removal at Reduced Coolant Inventory	107
5.4.5.4.1	Generic Letter 88-17 Requirements	107
5.4.5.4.2	Containment Closure	108
5.4.5.4.3	Instrumentation for Reduced Inventory Operation	109
5.4.5.4.4	Available Equipment to Mitigate Loss of Residual Heat Removal Cooling	110
5.4.5.4.5	Reduced Inventory Procedures	110
5.4.5.4.6	Analyses	111
5.4.5.5	Tests and Inspections	112
5.4.6	MAIN STEAM AND FEEDWATER PIPING	112
5.4.7	PRESSURIZER	113
5.4.7.1	System Description	113
5.4.7.2	Seismic Evaluation	114
5.4.8	PRESSURIZER RELIEF DISCHARGE SYSTEM	115
5.4.8.1	System Description	115
5.4.8.2	System Analysis	116
5.4.9	VALVES	116
5.4.9.1	Original Valve Design	116
5.4.9.2	Valve Wall Thickness	117
5.4.9.3	Motor-Operated Valve Program	117

5.4.10	SAFETY AND PRESSURIZER POWER OPERATED RELIEF VALVES (PORVs)	119
5.4.10.1	System Description	119
5.4.10.2	Performance Testing and Evaluation	120
5.4.11	COMPONENT SUPPORTS	121
5.4.11.1	Design Criteria	121
5.4.11.1.1	General	121
5.4.11.1.2	Asymmetric Loss-of-Coolant Accident Loading	121
5.4.11.1.3	Lamellar Tearing	122
5.4.11.2	Support Structures	122
5.4.11.2.1	Reactor Vessel Supports	122
5.4.11.2.2	Steam Generator Supports	123
5.4.11.2.3	Reactor Coolant Pump Supports	123
5.4.11.2.4	Pressurizer Supports	123
5.4.11.2.5	Reactor Coolant Piping Supports	123
5.4.11.2.6	Inspection and Testing	123
Table 5.4-1	REACTOR COOLANT PUMP DESIGN DATA	129
Table 5.4-2	REPLACEMENT STEAM GENERATOR DESIGN DATA	130
Table 5.4-3	REACTOR COOLANT PUMP COMPOSITE HOT PERFORMANCE CURVE DATA	131
Table 5.4-4	REACTOR COOLANT PUMPS COLD PERFORMANCE CURVE DATA FOR INDIVIDUAL IMPELLERS	133
Table 5.4-5	REACTOR VESSEL HEAD VENT EQUIPMENT PARAMETERS	134
Table 5.4-6	RESIDUAL HEAT REMOVAL SYSTEM COMPONENT DESIGN DATA	136
Table 5.4-7	PRESSURIZER DESIGN DATA	138
Table 5.4-8	PRESSURIZER RELIEF TANK DESIGN DATA	139
Table 5.4-9	VALVE AND PIPING INFORMATION	140

FIGURES

Figure 5.2-1	Figure DELETED
Figure 5.2-2	Figure DELETED
Figure 5.2-3	Reactor Coolant Leak Detection Sensitivity
Figure 5.3-1	Reactor Vessel Schematic
Figure 5.3-2	Identification and Location of Beltline Region Material
Figure 5.3-3	Arrangement of Surveillance Capsules in the Reactor Vessel
Figure 5.4-1	Reactor Coolant Pump
Figure 5.4-2	Reactor Coolant Pump Estimated Performance Characteristics
Figure 5.4-2a	Reactor Coolant Pump Composite Curve, Calculated Hot Performance, Total Head and Hydraulic Efficiency Versus Flow
Figure 5.4-2b	Reactor Coolant Pump Composite Curve, Calculated Hot Performance, Brake Horse- power Versus Flow
Figure 5.4-2c	Reactor Coolant Pump Composite Curve, Calculated Cold Performance, Total Head and Hydraulic Efficiency Versus Flow
Figure 5.4-2d	Reactor Coolant Pump Composite Curve, Calculated Cold Performance, Brake Horsepower Versus Flow
Figure 5.4-3	Reactor Coolant Pressure Shaft Seal Arrangement
Figure 5.4-4	Reactor Coolant Pump Flywheel
Figure 5.4-5	Reactor Coolant Pump Flywheel Primary Stress at Operating Speed
Figure 5.4-6	Replacement Steam Generator
Figure 5.4-7	Figure DELETED
Figure 5.4-8	Pressurizer
Figure 5.4-9	Pressurizer Relief Tank