

CHAPTER 3
REACTOR
TABLE OF CONTENTS

		<u>PAGE</u>
3.0	<u>REACTOR</u>	3.1-1
3.1	<u>GENERAL DESIGN SUMMARY</u>	3.1-1
3.2	<u>DESIGN BASIS</u>	3.2-1
3.2.1	PERFORMANCE OBJECTIVES	3.2-1
3.2.2	DESIGN OBJECTIVES	3.2-1
3.2.3	DESIGN LIMITS	3.2-1
	3.2.3.1 <u>Nuclear Design Limits</u>	3.2-1
	3.2.3.2 <u>Reactivity Control Design Limits</u>	3.2-2
	3.2.3.3 <u>Thermal and Hydraulic Design Limits</u>	3.2-2
	3.2.3.4 <u>Mechanical Design Limits</u>	3.2-2
	3.2.3.5 <u>Fuel Assembly Design Limits</u>	3.2-3
	3.2.3.6 <u>Control Element Assembly Design Limits</u>	3.2-4
3.2.4	REFERENCES	3.2.5
3.3	<u>MECHANICAL DESIGN</u>	3.3-1
3.3.1	SUMMARY	3.3-1
3.3.2	CORE MECHANICAL DESIGN	3.3-1
	3.3.2.1 <u>Fuel Rod Mechanical Design</u>	3.3-1
	3.3.2.2 <u>Burnable Poison Rod Mechanical Design</u>	3.3-2
	3.3.2.3 <u>Fuel Assembly Mechanical Design</u>	3.3-3
	3.3.2.4 <u>Control Element Assembly Mechanical Design</u>	3.3-7
	3.3.2.5 <u>Neutron Source Design</u>	3.3-9
	3.3.2.6 <u>Guide Tube Flux Suppressor Design</u>	3.3-9
	3.3.2.7 <u>Test Capsule Assembly Design</u>	3.3-9
	3.3.2.8 <u>ZIRLO Cladding (Westinghouse Fuel)</u>	3.3-10
	3.3.2.9 <u>M5 Cladding (AREVA/Framatome Fuel)</u>	3.3-11
	3.3.2.10 <u>Axial Blankets</u>	3.3-11
	3.3.2.11 <u>Radial Enrichment Zoning</u>	3.3-11
	3.3.2.12 <u>Armoring</u>	3.3-11
3.3.3	REACTOR INTERNAL STRUCTURES	3.3-11
	3.3.3.1 <u>Core Support Assembly</u>	3.3-12
	3.3.3.2 <u>Core Support Barrel</u>	3.3-12
	3.3.3.3 <u>Core Support Plate and Support Column</u>	3.3-13
	3.3.3.4 <u>Core Shroud</u>	3.3-13
	3.3.3.5 <u>Flow Skirt</u>	3.3-13
	3.3.3.6 <u>Upper Guide Structure Assembly</u>	3.3-14
3.3.4	CONTROL ELEMENT DRIVE MECHANISM	3.3-15
	3.3.4.1 <u>Design</u>	3.3-15
3.3.5	REFERENCES	3.3-16
3.4	<u>NUCLEAR DESIGN AND EVALUATION</u>	3.4-1

CHAPTER 3
REACTOR

TABLE OF CONTENTS

	<u>PAGE</u>	
3.4.1	SUMMARY	3.4-1
3.4.2	REACTIVITY AND CONTROL REQUIREMENTS	3.4-1
3.4.2.1	<u>Fuel Temperature Coefficient</u>	3.4-2
3.4.2.2	<u>Moderator Temperature Coefficient</u>	3.4-2
3.4.2.3	<u>Moderator Pressure Coefficient</u>	3.4-3
3.4.2.4	<u>Moderator Void Coefficient</u>	3.4-3
3.4.2.5	<u>Power Coefficient</u>	3.4-3
3.4.3	SHUTDOWN REACTIVITY CONTROL	3.4-4
3.4.3.1	<u>Shutdown Reactivity Margin</u>	3.4-4
3.4.3.2	<u>Power Defect</u>	3.4-5
3.4.3.3	<u>Control Element Assembly Bite and Power Dependent Insertion Limits</u>	3.4-5
3.4.3.4	<u>Shutdown Conditions</u>	3.4-6
3.4.4	CONTROL ELEMENT ASSEMBLY PATTERN, OPERATIONS, AND WORTHS	3.4-6
3.4.5	REACTIVITY INSERTION RATES	3.4-7
3.4.6	POWER DISTRIBUTION	3.4-7
3.4.6.1	<u>General</u>	3.4-7
3.4.6.2	<u>Objective</u>	3.4-7
3.4.6.3	<u>Fuel Management and Operations</u>	3.4-7
3.4.6.4	<u>Power Peaking Limits</u>	3.4-8
3.4.6.5	<u>Power Distribution Monitoring Capability</u>	3.4-8
3.4.7	REACTOR STABILITY	3.4-8
3.4.7.1	<u>General</u>	3.4-8
3.4.7.2	<u>Method of Analysis</u>	3.4-9
3.4.7.3	<u>Radial Stability</u>	3.4-9
3.4.7.4	<u>Azimuthal Stability</u>	3.4-10
3.4.7.5	<u>Axial Stability</u>	3.4-10
3.4.7.6	<u>Detection and Control of Oscillations</u>	3.4-10
3.4.8	NEUTRON FLUX AT PRESSURE VESSEL	3.4-10
3.4.9	ANALYTICAL METHODS	3.4-11
3.4.9.1	<u>General</u>	3.4-11
3.4.9.2	<u>Coarse-Mesh Diffusion Calculations - Westinghouse only</u>	3.4-12
3.4.9.3	<u>Power Distribution Monitoring</u>	3.4-12
3.4.10	REFERENCES	3.4-13
3.5	<u>THERMAL AND HYDRAULIC DESIGN AND EVALUATION</u>	3.5-1
3.5.1	GENERAL	3.5-1
3.5.1.1	<u>Cycle Summaries</u>	3.5-1

CHAPTER 3
REACTOR

TABLE OF CONTENTS

	<u>PAGE</u>	
3.5.2	THERMAL AND HYDRAULIC DESIGN BASES	3.5-12
3.5.2.1	<u>Minimum Departure from Nucleate Boiling Ratio</u>	3.5-12
3.5.2.2	<u>Fuel Design Basis</u>	3.5-12
3.5.2.3	<u>Hydraulic Stability</u>	3.5-13
3.5.3	STATISTICAL COMBINATION OF UNCERTAINTIES	3.5-13
3.5.4	REACTOR HYDRAULICS	3.5-13
3.5.4.1	<u>Coolant Flow</u>	3.5-13
3.5.4.2	<u>Pressure Losses</u>	3.5-14
3.5.4.3	<u>Partial Flow Operation</u>	3.5-14
3.5.5	MAXIMUM CORE TEMPERATURE	3.5-14
3.5.6	DEPARTURE FROM NUCLEATE BOILING	3.5-15
3.5.6.1	<u>Design Approach to Departure from Nucleate Boiling</u>	3.5-15
3.5.6.2	<u>Evaluation of Margin to DNB</u>	3.5-15
3.5.7	VAPOR FRACTION	3.5-15
3.5.8	THERMAL AND HYDRAULIC EVALUATION	3.5-16
3.5.8.1	<u>Statistical Analysis of Hot Channel Factors</u>	3.5-16
3.5.8.2	<u>Fuel Temperature Conditions</u>	3.5-16
3.5.8.3	<u>Flow Stability</u>	3.5-16
3.5.8.4	<u>AREVA/Framatome Fuel Assemblies</u>	3.5-16
3.5.9	REFERENCES	3.5-17
3.6	<u>ORIGINAL FUEL DESIGN EVALUATION</u>	3.6-1
3.6.1	FUEL DESIGN AND ANALYSIS	3.6-1
3.6.2	ANALYSIS OF BURNUP AND LINEAR HEAT RATINGS	3.6-2
3.6.3	SUMMARY OF PERTINENT FUELS IRRADIATION INFORMATION	3.6-3
3.6.3.1	<u>High Linear Heat Rating Irradiations</u>	3.6-3
3.6.3.2	<u>Shippingport Blanket Irradiations</u>	3.6-3
3.6.3.3	<u>NRX Irradiations (AECL - Canada)</u>	3.6-4
3.6.3.4	<u>Saxton Irradiations</u>	3.6-4
3.6.3.5	<u>Vallecitos Boiling Water Reactor - Dresden</u>	3.6-4
3.6.3.6	<u>Large Seed Blanket Reactor Rods</u>	3.6-5
3.6.3.7	<u>Central Melting in Big Rock</u>	3.6-5
3.6.3.8	<u>Peach Bottom 2</u>	3.6-5
3.6.4	EVALUATION	3.6-6
3.6.5	REFERENCES	3.6-6
3.7	<u>SUPPLEMENTARY FUEL DESIGN AND EVALUATION</u>	3.7-1
3.7.1	FUEL ROD DESIGN EVALUATION	3.7-1
3.7.1.1	<u>Mechanical Design Evaluation</u>	3.7-1
3.7.1.2	<u>Fuel Thermal Design Evaluation</u>	3.7-3

CHAPTER 3
REACTOR

TABLE OF CONTENTS

	<u>PAGE</u>	
3.7.1.3	<u>License Conditions with RODEX2 Methodology</u>	3.7-8
3.7.2	DESIGN EVALUATION OF OTHER FUEL ASSEMBLY COMPONENTS	3.7-9
3.7.2.1	<u>Burnable Poison Rod Design Evaluation</u>	3.7-9
3.7.2.2	<u>CEA Guide Tube Evaluation</u>	3.7-9
3.7.3	DEMONSTRATION PROGRAMS	3.7-10
3.7.3.1	<u>Introduction</u>	3.7-10
3.7.3.2	<u>CE/EPRI Fuel Performance Evaluation</u>	3.7-10
3.7.3.3	<u>CE Irradiation of Test Fuel Rods</u>	3.7-11
3.7.3.4	<u>SCOUT Program</u>	3.7-11
3.7.3.5	<u>PROTOTYPE Program</u>	3.7-11
3.7.3.6	<u>Materials Surveillance Specimens</u>	3.7-12
3.7.3.7	<u>Prototype CEA</u>	3.7-12
3.7.3.8	<u>ANF Demonstration Assemblies</u>	3.7-12
3.7.3.9	<u>Erbium Demonstration Assemblies</u>	3.7-12
3.7.3.10	<u>Test Capsule Assemblies</u>	3.7-13
3.7.3.11	<u>Lead Fuel Assemblies for Unit 2 Cycle 11</u>	3.7-13
3.7.3.12	<u>Batch 1RT Lead Fuel Assemblies</u>	3.7-13
3.7.3.13	<u>Framatome and Westinghouse Lead Fuel Assemblies for Unit 2 Cycle 15</u>	3.7-14
3.7.3.14	<u>Framatome Lead Test Assemblies for Unit 2 Cycle 24</u>	3.7-15
3.7.4	CHRONOLOGY OF FUEL EXPERIENCE	3.7-15
3.7.4.1	<u>Unit 1</u>	3.7-15
3.7.4.2	<u>Unit 2</u>	3.7-27
3.7.5	REFERENCES	3.7-35

CHAPTER 3
REACTOR
LIST OF TABLES

<u>TITLE</u>		<u>PAGE</u>
3.2-1	PRIMARY STRESS LIMITS FOR CRITICAL REACTOR VESSEL INTERNAL STRUCTURES	3.2-6
3.3-1	UNIT 1 BATCH-RELATED DATA	3.3-18
3.3-2	UNIT 2 BATCH-RELATED DATA	3.3-37
3.3-3	BURNABLE POISON ROD DATA	3.3-56
3.3-4	CONTROL ELEMENT ASSEMBLY DATA	3.3-58
3.3-5	CORE RELATED DATA	3.3-60
3.4-1	NUCLEAR PARAMETERS	3.4-15
3.4-2	CEA REACTIVITY WORTH AND ALLOWANCES, (% $\Delta\rho$)	3.4-17
3.5-1	DELETED	3.5-18
3.5-2	REACTOR COOLANT FLOWS IN BYPASS CHANNELS	3.5-19
3.5-3	DESIGN REACTOR PRESSURE LOSSES	3.5-20
3.6-1	TYPICAL PEAK BURNUP - MAXIMUM HEAT RELATIONSHIP	3.6-8
3.6-2	COMPARISON OF MAXIMUM HEAT RATINGS	3.6-9

CHAPTER 3
REACTOR

LIST OF FIGURES

FIGURE

3.1-1	REACTOR VERTICAL ARRANGEMENT
3.3-1	REACTOR CORE CROSS-SECTION
3.3-2	FIRST CYCLE FUEL ROD
3.3-3	FUEL ROD
3.3-3A	FUEL ROD ASSEMBLY (Westinghouse)
3.3-3B	FUEL ROD DESIGN (UNIT 2 CYCLE 16)
3.3-3C	FUEL ROD DESIGN (UNIT 1 CYCLES 18, 19, & 20 AND UNIT 2 CYCLES 17 & 18)
3.3-4 sh 1-47	BURNABLE POISON ROD LOCATION (Sheets 1 - 47)
3.3-5	FUEL ASSEMBLY
3.3-6	FUEL ASSEMBLY HOLD DOWN
3.3-7	CANTILEVER TAB FUEL SPACER GRID
3.3-7A	I-SPRING UNVANED SPACER GRID (TURBO)
3.3-7B	I-SPRING VANED SPACER GRID (TURBO)
3.3-8	CONTROL ELEMENT ASSEMBLY (CEA)
3.3-9A	WESTINGHOUSE/ABB-CE - CONTROL ELEMENT ASSEMBLIES
3.3-9B	AREVA/FRAMATOME - CONTROL ELEMENT ASSEMBLIES
3.3-10	CEA GROUP IDENTIFICATION
3.3-11	CORE ORIENTATION
3.3-12	PRESSURE VESSEL - CORE SUPPORT BARREL SNUBBER ASSEMBLY
3.3-13	CORE SHROUD ASSEMBLY
3.3-14	UPPER GUIDE STRUCTURE ASSEMBLY
3.3-15	CONTROL ELEMENT DRIVE MECHANISM (MAGNETIC JACK)
3.3-16	AREVA/FRAMATOME HTP FUEL ASSEMBLY, FUEL ROD, AND SPACER GRIDS
3.4-1	CYCLE 1 FUEL TEMPERATURE COEFFICIENT VS AVERAGE FUEL TEMPERATURE
3.4-2	CYCLE 1 POWER COEFFICIENT VS PERCENT OF FULL POWER (BEGINNING OF FIRST CYCLE)
3.4-3	FIRST CYCLE FUEL ASSEMBLY IDENTIFICATION BOTH UNITS
3.4-4	UNIT 1 CYCLE 25 QUARTER-CORE ASSEMBLY MAP
3.4-5	UNIT 2 CYCLE 24 QUARTER-CORE ASSEMBLY MAP
3.4-6	CYCLE 1 CORE POWER DISTRIBUTION, 2560 MWT (BEGINNING-OF-LIFE), NO XENON
3.4-7	UNIT 1 CYCLE 25 ASSEMBLY RELATIVE POWER DENSITY AT BOC, HFP, ARO, EQUILIBRIUM XENON
3.4-8	UNIT 2 CYCLE 24 ASSEMBLY RELATIVE POWER DENSITY AT BOC, HFP, ARO, EQUILIBRIUM XENON
3.4-9	CYCLE 1 CORE POWER DISTRIBUTION, 2560 MWT, 1000 MWD/MTU, EQUILIBRIUM XENON
3.4-10	UNIT 1 CYCLE 25 ASSEMBLY RELATIVE POWER DENSITY AT 10,000 MWd/MTU, HFP, ARO, EQUILIBRIUM XENON
3.4-11	UNIT 2 CYCLE 24 ASSEMBLY RELATIVE POWER DENSITY AT 10,000 MWd/MTU, HFP, ARO, EQUILIBRIUM XENON

CHAPTER 3
REACTOR
LIST OF FIGURES

FIGURE

3.4-12	CYCLE 1 CORE POWER DISTRIBUTION, 2560 MWT, END-OF-CYCLE, EQUILIBRIUM XENON
3.4-13	UNIT 1 CYCLE 25 ASSEMBLY RELATIVE POWER DENSITY AT EOC, HFP, ARO, EQUILIBRIUM XENON
3.4-14	UNIT 2 CYCLE 24 ASSEMBLY RELATIVE POWER DENSITY AT EOC, HFP, ARO, EQUILIBRIUM XENON
3.4-15	CORE POWER DISTRIBUTION – CEA GROUP 5 BEGINNING OF FIRST CYCLE, NO XENON
3.4-16	UNIT 1 CYCLE 25 ASSEMBLY RELATIVE POWER DENSITY WITH BANK 5 INSERTED TO PDIL AT BOC, HFP, EQUILIBRIUM XENON
3.4-17	UNIT 2 CYCLE 24 ASSEMBLY RELATIVE POWER DENSITY WITH BANK 5 INSERTED TO PDIL AT BOC, HFP, EQUILIBRIUM XENON
3.4-18	CORE POWER DISTRIBUTION – CEA GROUP 5 END-OF-CYCLE 1, EQUILIBRIUM
3.4-19	UNIT 1 CYCLE 25 ASSEMBLY RELATIVE POWER DENSITY WITH BANK 5 INSERTED TO PDIL AT EOC, HFP, EQUILIBRIUM XENON
3.4-20	UNIT 2 CYCLE 24 ASSEMBLY RELATIVE POWER DENSITY WITH BANK 5 INSERTED TO PDIL AT EOC, HFP, EQUILIBRIUM XENON
3.4-21	CORE POWER DISTRIBUTION - PART LENGTH CEA (P-1), BEGINNING OF FIRST CYCLE, NO XENON
3.4-22	CORE POWER DISTRIBUTION - PART LENGTH CEA (P-1), BEGINNING OF FIRST CYCLE, EQUILIBRIUM XENON
3.4-23	AXIAL PEAK VS % CEA INSERTION (BEGINNING OF FIRST CYCLE)
3.4-24	AXIAL PEAK VS CEA INSERTION WITH PART LENGTH CEAs (END OF FIRST CYCLE)
3.4-25	NUCLEAR HEAT FLUX PEAK VS CEA INSERTION (BEGINNING OF FIRST CYCLE)
3.4-26	NUCLEAR HEAT FLUX PEAK VS CEA INSERTION WITH PART LENGTH CEAs (END OF FIRST CYCLE)
3.4-27	FIRST CYCLE POWER DEPENDENT CEA INSERTION LIMITS
3.4-28	Deleted
3.7-1	FRAMATOME LEAD FUEL ASSEMBLY

CHAPTER 3
REACTOR

LIST OF ACRONYMS

ABB	Asea Brown Boveri, Inc.
ANF	Advanced Nuclear Fuel
AOO	Anticipated Operational Occurrence
APD	Axial Power Distribution
ARI	All Rods Inserted
ASI	Axial Shape Index
ASME	American Society of Mechanical Engineers
B&PV	Boiler and Pressure Vessel
BGE	Baltimore Gas and Electric Company
BOC	Beginning of Cycle
BOL	Beginning of Life
BPR	Burnable Poison Rods
CE	Combustion Engineering, Inc.
CEA	Control Element Assembly
CEDM	Control Element Drive Mechanism
CEDS	Control Element Drive System
CHF	Critical Heat Flux
CVCS	Chemical and Volume Control System
DBE	Design Basis Event
DNB	Departure from Nucleate Boiling
DNBR	Departure from Nucleate Boiling Ratio
ENDF	Evaluated Nuclear Data File
EOC	End of Cycle
EOL	End of Life
ESCU	Extended Statistical Combination of Uncertainties
ESFAS	Engineered Safety Feature Actuation Signal
FANP	Framatome Advanced Nuclear Power
FTC	Fuel Temperature Coefficient
GTFS	Guide Tube Flux Suppressor
HTP	High Thermal Performance
HMP	High Mechanical Performance
ICI	Incore Instrumentation
IFBA	Integral Fuel Burnable Absorber
LCO	Limiting Conditions for Operation
LEF	Lower End Fitting
LFA	Lead Fuel Assemblies
LHR	Linear Heat Rate
LOCA	Loss-of-Coolant Accident
LPD	Local Power Density
LSBR	Large Seed Blanket Reactor
LSSS	Limiting Safety System Setting
MDNBR	Minimum Departure from Nucleate Boiling Ratio
MRR	Most Reactive Rod
MTC	Moderator Temperature Coefficient

CHAPTER 3
REACTOR

LIST OF ACRONYMS

NEM	Nodal Expansion Method
NRC	Nuclear Regulatory Commission
PCI	Pellet-Clad Interaction
PDF	Probability Distribution Function
PDIL	Power Dependent Insertion Limit
PLCEA	Part Length Control Element Assembly
PLHR	Peak Linear Heat Rate
PWR	Pressurized Water Reactor
RCS	Reactor Coolant System
RPS	Reactor Protective System
RSS	Root-Sum-Square
SAFDL	Specified Acceptable Fuel Design Limit
SCU	Statistical Combination of Uncertainties
SS	Stainless Steel
T-H	Thermal Hydraulics
TD	Theoretical Density
TM/LP	Thermal Margin/Low Pressure
UGS	Upper Guide Structure
UO ₂	Uranium Oxide
VAP	Value Added Pellet
VBWR	Vallecitos Boiling Water Reactor
ZrB ₂	Zirc Diboride