

<u>4</u>	<u>REACTOR</u>	<u>1</u>
4.1	SUMMARY DESCRIPTION	2
4.1.1	REACTOR CORE	2
4.1.2	WESTINGHOUSE OPTIMIZED FUEL ASSEMBLIES/422 VAN-TAGE + FUEL ASSEMBLIES	2
4.1.3	RECONSTITUTED FUEL ASSEMBLIES	4
4.1.4	STARTUP REPORT	5
4.1	REFERENCES FOR SECTION 4.1	6
4.2	FUEL SYSTEM DESIGN	7
4.2.1	DESIGN BASES	7
4.2.1.1	Performance Objectives	7
4.2.1.2	Principal Design Criteria	7
4.2.1.2.1	Reactor Core Design	7
4.2.1.2.2	Suppression of Power Oscillations	9
4.2.1.2.3	Redundancy of Reactivity Control	9
4.2.1.2.4	Reactivity MODE 3 (Hot Shutdown) Capability	9
4.2.1.2.5	Reactivity Shutdown Capability	10
4.2.1.2.6	Reactivity Holddown Capability	10
4.2.1.2.7	Reactivity Control Systems Malfunction	11
4.2.1.2.8	Maximum Reactivity Worth of Control Rods	12
4.2.1.2.9	Conformance With 1972 General Design Criteria	12
4.2.1.3	Safety Limits	13
4.2.1.3.1	Nuclear Limits	13
4.2.1.3.2	Reactivity Control Limits	13
4.2.1.3.3	Thermal and Hydraulic Limits	13
4.2.1.3.4	Mechanical Limits	14
4.2.1.3.4.1	Reactor Internals	14
4.2.1.3.4.2	Fuel Assemblies	15
4.2.1.3.4.3	Control Rods	16
4.2.1.3.4.4	Control Rod Drive Assembly	16
4.2.2	FUEL SYSTEM DESIGN DESCRIPTION	16

4.2.3	CORE COMPONENTS DESIGN DESCRIPTION	17
4.2.3.1	Fuel Assembly	17
4.2.3.1.1	Top Nozzle, Springs, and Clamps	18
4.2.3.1.2	Bottom Nozzle	18
4.2.3.1.3	Guide Thimbles	19
4.2.3.1.4	Instrumentation Tube	19
4.2.3.1.5	Grid Assemblies	19
4.2.3.1.6	Fuel Rods	20
4.2.3.1.7	Fuel Assembly Joints and Connections	20
4.2.3.1.8	Fuel Assembly Identification	21
4.2.3.2	Control Rods	21
4.2.3.3	Neutron Source Assemblies	22
4.2.3.4	Plugging Devices	22
4.2.3.5	Fuel Pellet and Cladding Design Considerations	23
4.2.3.6	Reload Fuel Design	23
4.2.3.6.1	Reload Fuel Design - Westinghouse Optimized Fuel	23
4.2.3.6.2	Reload Fuel Design - Westinghouse OFA/VANTAGE + Fuel	24
4.2.3.6.3	Reload Fuel Design - Westinghouse 422V+ Fuel	24
4.2.3.7	Fuel Assembly and Rod Cluster Control Assembly Tests	24
4.2.3.7.1	Reactor Evaluation Center Tests	24
4.2.3.7.2	Loading and Handling Tests	24
4.2.3.7.3	Axial and Lateral Bending Tests	24
4.2.4	DESIGN EVALUATION	25
4.2.4.1	Fuel and Cladding Evaluation - Original Core	25
4.2.4.2	Design Evaluation - Reload Optimized Fuel Assembly, OFA/VANTAGE+ Fuel Assembly, and 422 VANTAGE+ Fuel Assembly Designs	25
4.2.4.2.1	Introduction	25
4.2.4.2.2	Fuel Design	26
4.2.4.2.3	Design for Seismic and Loss-of-Coolant Accident Forces	26
4.2.4.2.4	Emergency Core Cooling System (ECCS) Calculation Loss-of-Coolant Accident Cladding Models	26
4.2.4.2.5	Initial Fuel Conditions for Transient Analysis	26

4.2.4.2.6	Predicted Clad Collapse Time	26
4.2.4.2.7	Nuclear Design	27
4.2.4.2.8	Fuel Assembly Hydraulic Lift-Off	27
4.2.4.2.9	Thermal-Hydraulic Analysis	28
4.2.4.2.9.1	Sensitivity Factors	28
4.2.4.2.9.2	WRB-1 Correlation	28
4.2.4.2.9.3	Rod Bow Penalties	28
4.2.4.2.9.4	DNBR Design Limits	29
4.2.4.3	Design Evaluation of Reconstituted Fuel Assemblies	30
4.2.5	CORE COMPONENTS TESTS AND INSPECTIONS	30
4.2	REFERENCES FOR SECTION 4.2	31
Table 4.2-1	NUCLEAR DESIGN DATA	33
Table 4.2-2	CORE MECHANICAL DESIGN PARAMETERS	35
Table 4.2-3	FUEL DESIGN	38
Table 4.2-4	KINETIC PARAMETERS USED IN TRANSIENT ANALYSIS (WESTINGHOUSE OFA/VANTAGE+ AND 422V+ GINNA FUEL ASSEMBLY 14 x 14 FUEL)	39
4.3	RELOAD CORE NUCLEAR DESIGN	40
4.3.1	PRELIMINARY DESIGN PHASE	40
4.3.2	DETERMINATION OF NUCLEAR-RELATED KEY SAFETY PARAMETERS	41
4.3.2.1	Reactivity Control Aspects	41
4.3.2.1.1	Insertion Limits	42
4.3.2.1.2	Total Rod Worth	43
4.3.2.1.3	Trip Reactivity	43
4.3.2.1.4	Differential Rod Worths	43
4.3.2.1.5	Summary	44
4.3.2.2	Core Reactivity Parameters and Coefficients	44
4.3.2.2.1	Moderator Temperature Coefficient	44
4.3.2.2.2	Fuel Temperature Coefficient	45
4.3.2.2.3	Boron Worth	45
4.3.2.2.4	Delayed Neutrons	45
4.3.2.2.5	Prompt Neutron Lifetime	45
4.3.2.2.6	Summary	46

4.3.2.3	Reactor Core Power Distribution	46
4.3.3	EVALUATION OF RELOADS WITH OFA/VANTAGE+ AND 422V+ FUEL ASSEMBLIES	46
4.3.4	TESTS FOR REACTIVITY ANOMALIES	47
4.3	REFERENCES FOR SECTION 4.3	48
4.4	THERMAL AND HYDRAULIC DESIGN	49
4.4.1	DESIGN BASIS	49
4.4.2	DESCRIPTION AND EVALUATION OF THE THERMAL-HYDRAULIC DESIGN AND ANALYSIS OF RELOAD CORES	49
4.4.2.1	Hydraulic Evaluation	49
4.4.2.2	Thermal and Hydraulic Key Safety Parameters	49
4.4.2.2.1	Engineering Hot-Channel Factors	50
4.4.2.2.2	Axial Fuel Stack Shrinkage	50
4.4.2.2.3	Fuel Temperatures	50
4.4.2.2.4	Rod Internal Pressure	50
4.4.2.2.5	Core Thermal Limits	51
4.4.2.2.6	Key Safety Parameters for Specific Events	52
4.4.2.3	VIPRE Code	52
4.4.2.3.1	Steady-State Analysis	53
4.4.2.3.2	Transient Analysis	53
4.4.3	THERMAL-HYDRAULIC METHODOLOGY FOR OFA/VANTAGE+ and 422V+ FUEL ASSEMBLY DESIGN EVALUATION	53
4.4.3.1	General	53
4.4.3.2	Rod Bow	55
4.4.4	THERMAL AND HYDRAULIC TESTS AND INSPECTIONS	55
4.4.5	REACTOR COOLANT FLOW MEASUREMENT	55
4.4.5.1	Pump Power	56
4.4.5.2	Secondary Heat Balance	56
4.4.5.3	Elbow Tap Differential Pressure	56
4.4.5.4	Core Exit Thermocouple	56
4.4.5.5	Pump Power-Differential Pressure	57
4.4.5.6	Experience	58
4.4.5.7	Low Flow Trip Setpoint	59
4.4.5.8	Precision Calorimetric Measurement for Reactor Coolant System Flow	59
4.4	REFERENCES FOR SECTION 4.4	63
Table 4.4-1	THERMAL AND HYDRAULIC DESIGN PARAMETERS	65

4.5	REACTOR MATERIALS	67
4.5.1	CONTROL ROD DRIVE SYSTEM STRUCTURAL MATERIALS	67
4.5.2	REACTOR INTERNALS MATERIALS	67
4.6	FUNCTIONAL DESIGN OF REACTIVITY CONTROL SYSTEM	68

FIGURES

Figure 4.2-1	Typical Rod Cluster Control Assembly
Figure 4.2-2	Fuel Assembly and Control Cluster Cross Section
Figure 4.2-3	14 x 14 OFA and 422V+ Fuel Assemblies
Figure 4.2-4	OFA and 422V+ Top Nozzle Assemblies
Figure 4.2-5	Debris Filter Bottom Nozzle
Figure 4.2-6	Optimized Guide Thimble Assembly
Figure 4.2-7	Optimized Instrumentation Tube
Figure 4.2-8	Mid-Grid Connection
Figure 4.2-9	Removable Top Nozzle and Top Grid Connection
Figure 4.3-1	Control Rod Cluster Groups
Figure 4.4-1	Typical Pump Power Versus Flow Curves