

CHAPTER 4—REACTOR TABLE OF CONTENTS

| | | |
|-----|--|--------|
| 4.0 | REACTOR..... | 4.1-1 |
| 4.1 | Summary Description | 4.1-1 |
| | 4.1.1 Principal Design Requirements | 4.1-4 |
| | 4.1.2 References | 4.1-5 |
| 4.2 | Fuel System Design | 4.2-1 |
| | 4.2.1 Design Bases | 4.2-2 |
| | 4.2.1.1 Cladding | 4.2-2 |
| | 4.2.1.2 Fuel Material..... | 4.2-4 |
| | 4.2.1.3 Fuel Rod Performance | 4.2-4 |
| | 4.2.1.4 HMP End Grids and HTP Intermediate Grids..... | 4.2-5 |
| | 4.2.1.5 Fuel Assembly Structural and Thermal-Hydraulic Design | 4.2-6 |
| | 4.2.1.6 Rod Cluster Control and Neutron Source Assemblies | 4.2-11 |
| | 4.2.1.7 Surveillance Programs | 4.2-14 |
| | 4.2.2 Description and Design Drawings | 4.2-15 |
| | 4.2.2.1 Fuel Assembly Description..... | 4.2-15 |
| | 4.2.2.2 Spacer Grids Description | 4.2-15 |
| | 4.2.2.3 Quick Disconnect Mechanism Description | 4.2-17 |
| | 4.2.2.4 Top Nozzle Assembly Description..... | 4.2-17 |
| | 4.2.2.5 Hold-down Springs Description | 4.2-17 |
| | 4.2.2.6 Bottom Nozzle Description | 4.2-18 |
| | 4.2.2.7 MONOBLOC™ Guide Tubes Description | 4.2-18 |
| | 4.2.2.8 Fuel Rods Description | 4.2-19 |
| | 4.2.2.9 Rod Cluster Control Assemblies Description | 4.2-20 |
| | 4.2.2.10 Stationary Control Component Assemblies Description | 4.2-20 |
| | 4.2.3 Design Evaluation..... | 4.2-22 |
| | 4.2.3.1 Cladding | 4.2-23 |
| | 4.2.3.2 Fuel | 4.2-28 |

| | | |
|---------|---|--------|
| 4.2.3.3 | Fuel Rod Performance | 4.2-29 |
| 4.2.3.4 | Spacer Grids Evaluation..... | 4.2-31 |
| 4.2.3.5 | Fuel Assembly Design Evaluation..... | 4.2-32 |
| 4.2.3.6 | Reactivity Control, Neutron Source, and Thimble Plug Assemblies..... | 4.2-42 |
| 4.2.4 | Testing and Inspection Plan | 4.2-44 |
| 4.2.4.1 | Operating Experience..... | 4.2-45 |
| 4.2.4.2 | Fuel Assembly Prototype Testing..... | 4.2-47 |
| 4.2.4.3 | Fuel Assembly Component Testing | 4.2-50 |
| 4.2.4.4 | Testing and Inspection of New Fuel | 4.2-51 |
| 4.2.4.5 | On-Line Fuel System Monitoring..... | 4.2-52 |
| 4.2.4.6 | Postirradiation Surveillance..... | 4.2-53 |
| 4.2.5 | References | 4.2-53 |
| 4.3 | Nuclear Design..... | 4.3-1 |
| 4.3.1 | Design Bases | 4.3-1 |
| 4.3.1.1 | Fuel Burnup..... | 4.3-2 |
| 4.3.1.2 | Negative Reactivity Feedbacks (Reactivity Coefficient) | 4.3-3 |
| 4.3.1.3 | Core Design Lifetime..... | 4.3-3 |
| 4.3.1.4 | Fuel Replacement Program | 4.3-3 |
| 4.3.1.5 | Reactivity Coefficients | 4.3-4 |
| 4.3.1.6 | Control of Power Distribution..... | 4.3-4 |
| 4.3.1.7 | Maximum Controlled Reactivity Insertion Rate | 4.3-5 |
| 4.3.1.8 | Shutdown Margins..... | 4.3-5 |
| 4.3.1.9 | Stability..... | 4.3-6 |
| 4.3.2 | Description..... | 4.3-7 |
| 4.3.2.1 | Nuclear Design Description..... | 4.3-7 |
| 4.3.2.2 | Power Distribution | 4.3-10 |
| 4.3.2.3 | Reactivity Coefficients | 4.3-20 |
| 4.3.2.4 | Control Requirements | 4.3-23 |
| 4.3.2.5 | Control Rod Patterns and Reactivity Worths..... | 4.3-28 |
| 4.3.2.6 | Criticality of Reactor During Refueling | 4.3-29 |
| 4.3.2.7 | Stability..... | 4.3-29 |

| | | |
|----------|---|--------|
| 4.3.2.8 | Vessel Irradiation..... | 4.3-31 |
| 4.3.3 | Analytical Methods | 4.3-32 |
| 4.3.3.1 | Analytical Methodology Summary | 4.3-32 |
| 4.3.3.2 | Validation..... | 4.3-34 |
| 4.3.4 | Changes | 4.3-36 |
| 4.3.5 | References | 4.3-37 |
| 4.4 | Thermal-Hydraulic Design..... | 4.4-1 |
| 4.4.1 | Design Bases | 4.4-1 |
| 4.4.1.1 | Departure from Nucleate Boiling Design Basis | 4.4-1 |
| 4.4.1.2 | Fuel Temperature Design Basis..... | 4.4-2 |
| 4.4.1.3 | Core Flow Design Basis | 4.4-2 |
| 4.4.1.4 | Hydrodynamic Stability Design Basis..... | 4.4-3 |
| 4.4.1.5 | Additional Considerations..... | 4.4-3 |
| 4.4.2 | Description of Thermal-Hydraulic Design of the Reactor Core..... | 4.4-3 |
| 4.4.2.1 | Summary Comparison..... | 4.4-3 |
| 4.4.2.2 | Critical Heat Flux Ratios..... | 4.4-3 |
| 4.4.2.3 | Linear Heat Generation Rate | 4.4-4 |
| 4.4.2.4 | Void Fraction Distribution | 4.4-4 |
| 4.4.2.5 | Core Coolant Flow Distribution..... | 4.4-4 |
| 4.4.2.6 | Core Pressure Drops and Hydraulic Loads..... | 4.4-4 |
| 4.4.2.7 | Correlations and Physical Data | 4.4-5 |
| 4.4.2.8 | Thermal Effects of Operational Transients..... | 4.4-7 |
| 4.4.2.9 | Uncertainties in Estimates..... | 4.4-8 |
| 4.4.2.10 | Flux Tilt Considerations..... | 4.4-9 |
| 4.4.3 | Description of the Thermal and Hydraulic Design of the Reactor Coolant System..... | 4.4-10 |
| 4.4.3.1 | Plant Configuration Data | 4.4-10 |
| 4.4.3.2 | Operating Restrictions on Pumps..... | 4.4-10 |
| 4.4.3.3 | Power-Flow Operating Map (BWR)..... | 4.4-10 |
| 4.4.3.4 | Temperature-Power Operating Map (PWR)..... | 4.4-10 |
| 4.4.3.5 | Load-Following Characteristics | 4.4-11 |
| 4.4.3.6 | Thermal and Hydraulic Characteristics Summary Table | 4.4-11 |

| | | |
|---------|---|--------|
| 4.4.4 | Evaluation..... | 4.4-11 |
| 4.4.4.1 | Critical Heat Flux..... | 4.4-11 |
| 4.4.4.2 | Core Hydraulics..... | 4.4-13 |
| 4.4.4.3 | Influence of Power Distributions..... | 4.4-14 |
| 4.4.4.4 | Core Thermal Response | 4.4-15 |
| 4.4.4.5 | Analytical Methods | 4.4-15 |
| 4.4.5 | Testing and Verification..... | 4.4-18 |
| 4.4.5.1 | Tests Prior to Initial Criticality..... | 4.4-18 |
| 4.4.5.2 | Initial Power and Plant Operation..... | 4.4-19 |
| 4.4.5.3 | Component and Fuel Inspections..... | 4.4-19 |
| 4.4.6 | Instrumentation Requirements | 4.4-19 |
| 4.4.6.1 | Fixed Incore Instrumentation..... | 4.4-19 |
| 4.4.6.2 | Aeroball Measurement System | 4.4-20 |
| 4.4.6.3 | Excore Neutron Instrumentation..... | 4.4-21 |
| 4.4.6.4 | Low DNBR I&C Functions | 4.4-23 |
| 4.4.6.5 | High Linear Power Density Functions | 4.4-24 |
| 4.4.6.6 | Loose Parts Monitoring System | 4.4-24 |
| 4.4.7 | References | 4.4-25 |
| 4.5 | REACTOR MATERIALS | 4.5-1 |
| 4.5.1 | Control Rod Drive System Structural Materials..... | 4.5-1 |
| 4.5.1.1 | Materials Specifications..... | 4.5-1 |
| 4.5.1.2 | Austenitic Stainless Steel Components..... | 4.5-2 |
| 4.5.1.3 | Other Materials..... | 4.5-2 |
| 4.5.1.4 | Cleaning and Cleanliness Control | 4.5-3 |
| 4.5.2 | Reactor Internals and Core Support Materials | 4.5-3 |
| 4.5.2.1 | Materials Specifications..... | 4.5-4 |
| 4.5.2.2 | Controls on Welding..... | 4.5-4 |
| 4.5.2.3 | Nondestructive Examination..... | 4.5-4 |
| 4.5.2.4 | Fabrication and Processing of Austenitic Stainless Steel Components..... | 4.5-4 |
| 4.5.2.5 | Other Materials..... | 4.5-5 |
| 4.5.3 | References | 4.5-5 |
| 4.6 | Functional Design of Reactivity Control Systems..... | 4.6-1 |



| | | |
|-------|--|-------|
| 4.6.1 | Information for Control Rod Drive System..... | 4.6-2 |
| 4.6.2 | Evaluation of the Control Rod Drive System | 4.6-3 |
| 4.6.3 | Testing and Verification of the Control Rod Drive System | 4.6-4 |
| 4.6.4 | Information for Combined Performance of Reactivity Systems..... | 4.6-5 |
| 4.6.5 | Evaluation of Combined Performance..... | 4.6-7 |
| 4.6.6 | References | 4.6-8 |