



GE Nuclear Energy

**26A6642AB
Revision 1
January 2006**



ESBWR Design Control Document

Tier 2

Table of Contents



1. Introduction and General Description of Plant

1.1 Introduction

- 1.1.1 Format and Content
- 1.1.2 General Description
 - 1.1.2.1 ESBWR Standard Plant Scope
 - 1.1.2.2 Type of License Request
 - 1.1.2.3 Number of Plant Units
 - 1.1.2.4 Description of Location
 - 1.1.2.5 Type of Nuclear Steam Supply
 - 1.1.2.6 Type of Containment
 - 1.1.2.7 Rated Core Thermal Power
- 1.1.3 COL Information
- 1.1.4 References

1.2 General Plant Description

- 1.2.1 Principal Design Criteria
 - 1.2.1.1 General Power Generation (Nonsafety) Design Criteria
 - 1.2.1.2 General Safety Design Criteria
 - 1.2.1.3 Nuclear System Criteria
 - 1.2.1.4 Electrical Power Systems Criteria
 - 1.2.1.5 Auxiliary Systems Criteria
 - 1.2.1.6 Shielding and Access Control Criteria
 - 1.2.1.7 Power Conversion Systems Criteria
 - 1.2.1.8 Nuclear System Process Control Criteria
 - 1.2.1.9 Electrical Power System Process Control Criteria
- 1.2.2 Plant Description
 - 1.2.2.1 Nuclear Steam Supply
 - 1.2.2.2 Controls and Instrumentation
 - 1.2.2.3 Radiation Monitoring Systems
 - 1.2.2.4 Core Cooling Systems Used For Abnormal Events
 - 1.2.2.5 Reactor Servicing Equipment
 - 1.2.2.6 Reactor Auxiliary Systems
 - 1.2.2.7 Control Panels
 - 1.2.2.8 Nuclear Fuel
 - 1.2.2.9 Control Rods
 - 1.2.2.10 Radioactive Waste Management System
 - 1.2.2.11 Power Cycle
 - 1.2.2.12 Station Auxiliaries
 - 1.2.2.13 Station Electrical System
 - 1.2.2.14 Power Transmission
 - 1.2.2.15 Containment and Environmental Control Systems
 - 1.2.2.16 Structures and Servicing Systems
 - 1.2.2.17 Intake Structure and Servicing Equipment
 - 1.2.2.18 Yard Structures and Equipment
- 1.2.3 COL Information

1.2.4 References

1.3 Comparison Tables

1.4 Identification of Agents and Contractors

1.5 Requirements for Further Technical Information

1.5.1 Evolutionary Design

1.5.2 Analysis and Design Tools

1.5.2.1 TRACG

1.5.2.2 Scope of Application of TRACG to ESBWR

1.5.3 Testing

1.5.3.1 Major ESBWR Unique Test Programs

1.5.4 References

1.6 Material Incorporated by Reference

1.7 Drawings and Other Detailed Information

1.7.1 Electrical, Instrumentation and Control Drawings

1.7.2 Piping and Instrumentation Diagrams

1.7.3 Other Detailed Information

1.8 Interfaces for Standard Designs

1.8.1 Identification of NSSS Safety-Related Interfaces

1.8.2 Identification of BOP Interfaces

1.8.2.1 Circulating Water System (CIRC)

1.8.2.2 Plant Service Water System (PSWS)

1.8.2.3 Off-site Electrical Power

1.8.2.4 Makeup Water System (MWS)

1.8.2.5 Potable and Sanitary Water

1.8.2.6 Communications Systems

1.9 Conformance with Standard Review Plan and Applicability of Codes and Standards

1.9.1 Conformance with Standard Review Plan

1.9.2 Applicability to Regulatory Criteria

1.9.3 Applicability of Experience Information

1.9.4 COL information

1.9.4.1 SRP Deviations

1.9.4.2 Experience Information

1.9.5 References

1.10 Summary of COL Items

1.11 Technical Resolutions of Task Action Plan Items, New Generic Issues, New Generic Safety Issues and Chernobyl Issues

1.11.1 Approach

Appendix 1A Response to TMI Related Matters

1A.1 References

Appendix 1B Plant Shielding to Provide Access to Vital Areas and Protective Safety Equipment for Post-Accident Operation [II.B.2]

1B.1 Introduction

1B.2 Summary of Shielding Design Review

1B.3 Containment Description and Post-Accident Operations

1B.3.1 Description of Containment

1B.3.2 Post-Accident Access of Vital Areas and Systems

1B.3.3 Post-Accident Operation

1B.4 Design Review Bases

1B.4.1 Radioactive Source Term and Dose Rates

1B.4.2 Accidents Used as the Basis for the Specified Radioactivity Release

1B.4.3 Availability of Offsite Power

1B.4.4 Radiation Qualification Conditions

1B.5 Results of the Review

1B.5.1 Systems Required Post-Accident

1B.5.1.1 Necessary Post-Accident Functions and Systems

1B.5.1.2 Emergency Core Cooling and Residual Heat Removal Systems

1B.5.1.3 Flammability Control

1B.5.1.4 Fission Product Removal and Control System

1B.5.1.5 Instrumentation and Control, Power and Habitability Systems

Appendix 1C Industry Operating Experience

1C.1 Evaluation

Appendix 1D Regulatory Treatment of Non-Safety Systems

1D.1 Review of RTNSS Criteria

1D.2 Specific Steps in the RTNSS Process

1D.3 Conclusion

1D.4 COL Information

1D.5 References

2. Site Characteristics

2.0 Introduction

2.1 Geography and Demography

- 2.1.1 Site and Location Description
- 2.1.2 Exclusion Area Authority and Control
- 2.1.3 Population Distribution

2.2 Nearby Industrial, Transportation, and Military Facilities

- 2.2.1 – 2.2.2 Identification of Potential Hazards in Site Vicinity
- 2.2.3 Evaluation of Postulated Accidents

2.3 Meteorology

- 2.3.1 Regional Climatology
- 2.3.2 Local Meteorology
- 2.3.3 On-site Meteorological Measurements Program
- 2.3.4 Short-Term Diffusion Estimates for Accidental Atmospheric Releases
- 2.3.5 Long-Term Diffusion Estimates

2.4 Hydrologic Engineering

- 2.4.1 Hydrologic Description
- 2.4.2 Floods
- 2.4.3 Probable Maximum Flood on Streams and Rivers
- 2.4.4 Potential Dam Failures
- 2.4.5 Probable Maximum Surge and Seiche Flooding
- 2.4.6 Probable Maximum Tsunami Flooding
- 2.4.7 Ice Effects
- 2.4.8 Cooling Water Canals and Reservoirs
- 2.4.9 Channel Diversions
- 2.4.10 Flooding Protection Requirements
- 2.4.11 Cooling Water Supply
- 2.4.12 Groundwater
- 2.4.13 Accidental Releases of Liquid Effluents in Ground and Surface Waters
- 2.4.14 Technical Specification and Emergency Operation Requirements

2.5 Geology, Seismology, and Geotechnical Engineering

- 2.5.1 Basic Geologic and Seismic Information
 - 2.5.1.1 Regional Geology
 - 2.5.1.2 Site Geology
- 2.5.2 Vibratory Ground Motion
- 2.5.3 Surface Faulting
- 2.5.4 Stability of Subsurface Materials and Foundations
- 2.5.5 Stability of Slopes

3. Design of Structures, Components, Equipment, and Systems

3.1 CONFORMANCE WITH NRC GENRAL DESIGN CRITERIA

- 3.1.1 Group I — Overall Requirements
- 3.1.2 Group II — Protection by Multiple Fission Product Barriers
- 3.1.3 Group III — Protection and Reactivity Control Systems
- 3.1.4 Group IV — Fluid Systems
- 3.1.5 Group V — Reactor Containment
- 3.1.6 Group VI — Fuel and Radioactivity Control
- 3.1.7 COL Information

3.2 CLASSIFICATION OF STRUCTURES, STYSTEMS AND COMPONENTS

- 3.2.1 Seismic Classification
- 3.2.2 System Quality Group Classification
- 3.2.3 Safety Classification
- 3.2.4 COL Information
- 3.2.5 References

3.3 WIND AND TORNADO LOADINGS

- 3.3.1 Wind Loadings
- 3.3.2 Tornado Loadings
- 3.3.3 COL Information
- 3.3.4 References

3.4 WATER LEVEL (FLOOD) DESIGN

- 3.4.1 Flood Protection
- 3.4.2 Analysis Procedures
- 3.4.3 COL Information

3.5 MISSILE PROTECTION

- 3.5.1 Missile Selection and Description
- 3.5.2 Structures, Systems, and Components to be Protected from Externally Generated Missiles
- 3.5.3 Barrier Design Procedures
- 3.5.4 COL Information
- 3.5.5 References

3.6 PROTECTION AGAINST DYNAMIC EFFECTS ASSOCIATED WITH THE POSTULATED RUPTURE OF PIPING

- 3.6.1 Plant Design for Protection Against Postulated Piping Failures in Fluid Systems Inside and Outside of Containment
- 3.6.2 Determination of Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping
- 3.6.3 Leak-Before-Break Evaluation Procedures
- 3.6.4 As-built Inspection of High-Energy Pipe Break Mitigation Features
- 3.6.5 COL Information
- 3.6.6 References

3.7 SEISMIC DESIGN

- 3.7.1 Seismic Design Parameters
- 3.7.2 Seismic System Analysis
- 3.7.3 Seismic Subsystem Analysis
- 3.7.4 Seismic Instrumentation
- 3.7.5 COL Information
- 3.7.6 References

3.8 SEISMIC CATEGORY I STRUCTURES

- 3.8.1 Concrete Containment
- 3.8.2 Steel Components of the Reinforced Concrete Containment
- 3.8.3 Concrete and Steel Internal Structures of the Concrete Containment
- 3.8.4 Other Seismic Category I Structures
- 3.8.5 Foundations
- 3.8.6 COL Information

3.9 MECHANICAL SYSTEMS AND COMPONENTS

- 3.9.1 Special Topics for Mechanical Components
- 3.9.2 Dynamic Testing and Analysis of Systems, Components and Equipment
- 3.9.3 ASME Code Class 1, 2 and 3 Components, Component Supports and Core Support Structures
- 3.9.4 Control Rod Drive (CRD) System
- 3.9.5 Reactor Pressure Vessel Internals
- 3.9.6 In-Service Testing of Pumps and Valves
- 3.9.7 Risk-Informed In-Service Testing
- 3.9.8 Risk-Informed In-Service Inspection of Piping
- 3.9.9 COL Information
- 3.9.10 References

3.10 SEISMIC AND DYNAMIC QUALIFICATION OF MECHANICAL AND ELECTRICAL EQUIPMENT

- 3.10.1 Seismic and Dynamic Qualification Criteria
- 3.10.2 Methods and Procedures for Qualifying Electrical Equipment
- 3.10.3 Analysis or Testing of Electrical Equipment Supports
- 3.10.4 Combined Operating License Information
- 3.10.5 References

3.11 ENVIRONMENTAL QUALIFICATION OF MECHANICAL AND ELECTRICAL EQUIPMENT

- 3.11.1 Equipment Identification
- 3.11.2 Environmental Conditions
- 3.11.3 Loss of Heating, Ventilating and Air Conditioning
- 3.11.4 Estimated Chemical and Radiation Environment
- 3.11.5 Combined Operating License Information
- 3.11.6 References

APPENDIX 3A SEISMIC SOIL-STRUCTURE INTERACTION ANALYSIS

- 3A.1 Introduction
- 3A.2 ESBWR Standard Plant Site Plan
- 3A.3 Site Conditions
 - 3A.3.1 Generic Site Conditions
 - 3A.3.2 North Anna ESP Site Conditions
- 3A.4 Input Motion and Damping Values
 - 3A.4.1 Input Motion
 - 3A.4.2 Damping Values
- 3A.5 Soil-Structure Interaction Analysis Method
- 3A.6 Soil-Structure Interaction Analysis Cases
- 3A.7 Analysis Models
 - 3A.7.1 Method of Dynamic Structural Model Development
 - 3A.7.2 Lumped Mass-Beam Stick Model for SSI Analysis
- 3A.8 Analysis Results
- 3A.9 Site Envelope Seismic Responses
 - 3A.9.1 Enveloping Maximum Structural Loads
 - 3A.9.2 Enveloping Floor Response Spectra

APPENDIX 3B CONTAINMENT HYDRODYNAMIC LOADS

- 3B.1 Safety Relief Valve (SRV) Loads
- 3B.2 Accident Pressure Loads
- 3B.3 References

APPENDIX 3C COMPUTER PROGRAMS USED IN THE DESIGN AND ANALYSIS OF SEISMIC CATEGORY I STRUCTURES

- 3C.1 Introduction
- 3C.2 Static and Dynamic Structural Analysis Program (NASTRAN)
- 3C.3 ABAQUS and ANACAP-U
- 3C.4 Concrete Element Cracking Analysis Program (SSDP-2D)
- 3C.5 Heat Transfer Analysis Program (TEMCOM2)
- 3C.6 Static and Dynamic Structural Analysis Systems: ANSYS
- 3C.7 Soil-Structure Interaction

APPENDIX 3D COMPUTER PROGRAMS USED IN THE DESIGN OF COMPONENTS, EQUIPMENT AND STRUCTURES

- 3D.1 Introduction
- 3D.2 Fine Motion Control Rod Drive
- 3D.3 Reactor Pressure Vessel and Internals
- 3D.4 Piping
- 3D.5 Pumps and Motors
- 3D.6 Heat Exchangers
- 3D.7 References

APPENDIX 3E GUIDELINE FOR LEAK BEFORE BREAK APPLICATIONS

3E.1 Introduction**3E.1.1 Material Selection Guidelines****3E.1.2 Deterministic Evaluation Procedure****3E.2 Material Fracture Toughness Characterization****3E.2.1 Fracture Toughness Characterization****3E.2.2 Carbon Steels and Associated Welds****3E.2.3 Stainless Steels and Associated Welds****3E.3 Fracture Mechanics Methods****3E.3.1 Elastic-Plastic Fracture Mechanics or (J/T) Methodology****3E.3.2 Application of (J/T) Methodology to Carbon Steel Piping****3E.3.3 Modified Limit Load Methodology for Austenitic Stainless Steel Piping****3E.3.4 Bimetallic Welds****3E.4 Leak Rate Calculation Methods****3E.4.1 Leak Rate Estimation for Pipes Carrying Water****3E.4.2 Flow Rate Estimation for Saturated Steam****3E.5 Leak Detection Capabilities****3E.6 References****APPENDIX 3F RESPONSE OF STRUCTURES TO CONTAINMENT LOADS****3F.1 Scope****3F.2 Dynamic Response****3F.2.1 Classification of Analytical Procedure****3F.2.2 Analysis Models****3F.2.3 Load Application****3F.2.4 Analysis Method****3F.3 Containment Loads Analysis Results****APPENDIX 3G DESIGN DETAILS AND EVALUATION RESULTS OF SEISMIC
CATEGORY I STRUCTURES****3G.1 Reactor Building****3G.1.1 Objective and Scope****3G.1.2 Conclusions****3G.1.3 Structural Description****3G.1.3.1 Description of the Reactor Building****3G.1.4 Analytical Models****3G.1.4.1 Structural Models****3G.1.4.2 Foundation Models****3G.1.5 Structural Analysis and Design****3G.1.5.1 Site Design Parameters****3G.1.5.2 Design Loads, Load Combinations, and Material Properties****3G.1.5.3 Stability Requirements****3G.1.5.4 Structural Design Evaluation****3G.1.5.5 Foundation Stability****3G.1.5.6 Tornado Missile Evaluation****3G.1.6 References****3G.2 Control Building**

- 3G.2.1 Objective and Scope
- 3G.2.2 Conclusions
- 3G.2.3 Structural Description
- 3G.2.4 Analytical Models
 - 3G.2.4.1 Structural Model
 - 3G.2.4.2 Foundation Models
- 3G.2.5 Structural Analysis and Design
 - 3G.2.5.1 Site Design Parameters
 - 3G.2.5.2 Design Loads, Load Combinations, and Material Properties
 - 3G.2.5.3 Stability Requirements
 - 3G.2.5.4 Structural Design Evaluation
 - 3G.2.5.5 Foundation Stability
 - 3G.2.5.6 Tornado Missile Evaluation
- 3G.3 Fuel Building
 - 3G.3.1 Objective and Scope
 - 3G.3.2 Conclusions
 - 3G.3.3 Structural Description
 - 3G.3.4 Analytical Models
 - 3G.3.5 Structural Analysis and Design
 - 3G.3.5.1 Site Design Parameters
 - 3G.3.5.2 Design Loads, Load Combinations, and Material Properties
 - 3G.3.5.3 Stability Requirements
 - 3G.3.5.4 Structural Design Evaluation
 - 3G.3.5.5 Foundation Stability
 - 3G.3.5.6 Tornado Missile Evaluation

APPENDIS 3H EQUIPMENT QUALIFICATION DESIGN ENVIRONMENTAL CONDITIONS

- 3H.1 Introduction
- 3H.2 Plant Zones
 - 3H.2.1 Containment Vessel
 - 3H.2.2 Outside Containment Vessel
- 3H.3 Environmental Conditions
 - 3H.3.1 Plant Normal Operating Conditions
 - 3H.3.2 Accident Conditions
 - 3H.3.3 Water Quality
- 3H.4 References

APPENDIX 3I DESIGNATED NEDE-24326-1-P MATERIAL WHICH MAY NOT CHANGE WITHOUT PRIOR NRC APPROVAL

- 3I.1 General Requirements for Dynamic Testing
- 3I.2 Product and Assembly Testing
- 3I.3 Multiple-Frequency Tests
- 3I.4 Single- and Multi-axis Tests
- 3I.5 Single Frequency Tests
- 3I.6 Damping

- 3I.7 Qualification Determination
- 3I.8 Dynamic Qualification by Analysis
- 3I.9 Required Response Spectra
- 3I.10 Time History Analysis
- 3I.11 References

APPENDIX 3J EVALUATION OF POSTULATED RUPTURES IN HIGH ENERGY PIPES

- 3J.1 Background and Scope
- 3J.2 Identification of Rupture Locations and Rupture Geometry
 - 3J.2.1 Ruptures in Containment Penetration Area.
 - 3J.2.2 Ruptures in Areas other than Containment Penetration.
 - 3J.2.3 Determine the Type of Pipe Break
- 3J.3 Design and Selection of Pipe Whip Restraints
 - 3J.3.1 Make Preliminary Selection of Pipe Whip Restraint
 - 3J.3.2 Prepare Simplified Computer Model of Piping-Pipe Whip Restraint System.
 - 3J.3.3 Run Pipe Dynamic Analysis
 - 3J.3.4 Select Pipe Whip Restraint for Pipe Whip Restraint Analysis
- 3J.4 Pipe Rupture Evaluation
 - 3J.4.1 General Approach
 - 3J.4.2 Procedure For Dynamic Time-History Analysis With Simplified Model
 - 3J.4.2.1 Modeling of Piping System
 - 3J.4.2.2 Dynamic Analysis of Simplified Piping Model
 - 3J.4.3 Procedure For Dynamic Time-History Analysis Using Detailed Piping Model
 - 3J.4.3.1 Modeling of Piping System
 - 3J.4.3.2 Dynamic Analysis using Detail Piping Model
- 3J.5 Jet Impingement on Essential Piping

APPENDIX 3K RESOLUTION OF INTERSYSTEM LOSS OF COOLANT ACCIDENT

- 3K.1 Introduction
- 3K.2 Regulatory Positions
- 3K.3 Boundary Limits of Ultimate Rupture Strength
- 3K.4 Evaluation Procedure
- 3K.5 Systems Evaluated
- 3K.6 Piping Design Pressure for Ultimate Rupture Strength Compliance
- 3K.7 Applicability of Ultimate Rupture Strength Non-piping Components
- 3K.8 Results
- 3K.9 Valve Misalignment Due To Operator Error
- 3K.10 Summary
- 3K.11 References

Attachment 3KA. ULTIMATE RUPTURE STRENGTH SYSTEM BOUNDARY EVALUATION

- 3KA.1 Control Rod Drive System
- 3KA.2 Standby Liquid Control System
- 3KA.3 Reactor Water Cleanup/Shutdown Cooling System

3KA.4 Fuel And Auxiliary Pools Cooling System

3KA.5 Nuclear Boiler System

3KA.6 Condensate And Feedwater System

APPENDIX 3L REACTOR INTERNALS FLOW INDUCED VIBRATION PROGRAM

3L.1 Introduction

3L.2 Reactor Internal Components FIV Evaluation

3L.3 Chimney Partition Assembly Evaluation

3L.4 Steam Dryer Evaluation Program

3L.5 Startup Test Program

3L.6 References

4. Reactor

4.1 Summary Description

- 4.1.1 Reactor Pressure Vessel
- 4.1.2 Reactor Internal Components
 - 4.1.2.1 Reactor Core
- 4.1.3 Reactivity Control Systems
- 4.1.4 Analysis Techniques
- 4.1.5 COL Information
- 4.1.6 References

4.2 Fuel System Design

- 4.2.1 Design Bases
 - 4.2.1.1 Fuel Assembly
 - 4.2.1.2 Control Rods
- 4.2.2 Description and Design Drawings
- 4.2.3 Fuel Assembly Design Evaluations
- 4.2.4 Control Rod Design Evaluations
- 4.2.5 Testing, Inspection, and Surveillance Plans
- 4.2.6 COL Information
- 4.2.7 References

4.3 Nuclear Design

- 4.3.1 Design Basis
 - 4.3.1.1 Negative Reactivity Feedback Bases
 - 4.3.1.2 Control Requirements (Shutdown Margins)
 - 4.3.1.3 Control Requirements (Overpower Bases)
 - 4.3.1.4 Control Requirements (Standby Liquid Control System)
 - 4.3.1.5 Stability Bases
- 4.3.2 Nuclear Design Analytical Methods
- 4.3.3 Nuclear Design Evaluation
- 4.3.4 Changes
- 4.3.5 COL Information
- 4.3.6 References
- 4.4 Thermal and Hydraulic Design
 - 4.4.1 Reactor Core Thermal and Hydraulic Design Basis
 - 4.4.2 Reactor Core Thermal and Hydraulic Methods
 - 4.4.3 Reactor Core Thermal and Hydraulic Evaluations
 - 4.4.4 Description of the Thermal–Hydraulic Design of the Reactor Coolant System
 - 4.4.5 Loose-Parts Monitoring System
 - 4.4.6 Testing and Verification
 - 4.4.7 COL Information
 - 4.4.7.1 Reactor Core Thermal and Hydraulic Design
 - 4.4.8 References

4.5 Reactor Materials

4.5.1 Control Rod Drive System Structural Materials

4.5.2 Reactor Internal Materials

4.5.3 COL Information

4.5.3.1 CRD Inspection Program

4.5.4 References

4.6 Functional Design of Reactivity Control System

4.6.1 Information for Control Rod Drive System

4.6.2 Evaluations of the CRD System

4.6.3 Testing and Verification of the CRDs

4.6.4 Information for Combined Performance of Reactivity Control Systems

4.6.5 Evaluation of Combined Performance

4.6.6 COL Information

4.6.7 References

Appendix 4A.1 Introduction

4A.2 Results of Core Simulation Studies

4A.3 COL Information

Appendix 4B.1 General Criteria

4B.2 Thermal-Mechanical

4B.3 Nuclear

4B.4 Hydraulic

4B.5 Operating Limit MCPR

4B.6 Critical Power Correlation

4B.7 Stability

4B.8 Overpressure Protection Analysis

4B.9 Refueling Accident Analysis

4B.10 Anticipated Transient Without Scram

4B.11 COL Information

4B.12 References

Appendix 4C.1 General Criteria

4C.2 Basis for Acceptance Criteria

4C.3 COL Information

Appendix 4D.1 Stability Performance During Power Operation

4D.1.1 Stability Criteria

4D.1.2 Analysis Methods

4D.1.3 Steady State Stability Performance

4D.1.3.1 Baseline Analysis

4D.1.4 Statistical Analysis of ESBWR Stability

4D.2 Stability Performance During Plant Startup

4D.2.1 Phenomena Governing Oscillations during Startup

4D.2.2 TRACG Analysis of Typical Startup Trajectories

4D.3 COL Information

4D.4 References

5. Reactor Coolant System and Connected Systems

5.1 Summary Description

- 5.1.1 Schematic Flow Diagrams
- 5.1.2 Piping and Instrumentation Schematics
- 5.1.3 Elevation Schematics

5.2 Integrity of Reactor Coolant Pressure Boundary

- 5.2.1 Compliance with Codes and Code Cases
 - 5.2.1.1 Compliance with 10 CFR 50, Section 50.55a
 - 5.2.1.2 Applicable Code Cases
- 5.2.2 Overpressure Protection
- 5.2.3 Reactor Coolant Pressure Boundary Materials
 - 5.2.3.1 Material Specifications
 - 5.2.3.2 Compatibility with Reactor Coolant
 - 5.2.3.3 Fabrication and Processing of Ferritic Materials
 - 5.2.3.4 Fabrication and Processing of Austenitic Stainless Steels
- 5.2.4 Preservice and Inservice Inspection and Testing of Reactor Coolant Pressure Boundary
 - 5.2.4.1 Class 1 System Boundary
 - 5.2.4.2 Accessibility
 - 5.2.4.3 Examination Categories and Methods
 - 5.2.4.4 Inspection Intervals
 - 5.2.4.5 Evaluation of Examination Results
 - 5.2.4.6 System Leakage and Hydrostatic Pressure Tests
 - 5.2.4.7 Code Exemptions
 - 5.2.4.8 Code Cases
- 5.2.5 Reactor Coolant Pressure Boundary (RCPB) Leakage Detection
 - 5.2.5.1 Leakage Detection Methods
 - 5.2.5.2 Leak Detection Instrumentation and Monitoring
 - 5.2.5.3 Display and Indications in the Main Control Room
 - 5.2.5.4 Limits for Reactor Coolant Leakage Rates Within the Drywell
 - 5.2.5.5 Criteria to Evaluate the Adequacy and Margin of Leak Detection System
 - 5.2.5.6 Separation of Identified and Unidentified Leakages in the Containment
 - 5.2.5.7 Testing, Calibration and Inspection Requirements
 - 5.2.5.8 Regulatory Guide 1.45 Compliance
- 5.2.6 COL Information
- 5.2.7 References

5.3 Reactor Vessel

- 5.3.1 Reactor Vessel Materials
 - 5.3.1.1 Materials Specifications
 - 5.3.1.2 Special Procedures Used for Manufacturing and Fabrication
 - 5.3.1.3 Special Methods for Nondestructive Examination
 - 5.3.1.4 Special Controls for Ferritic and Austenitic Stainless Steels
 - 5.3.1.5 Fracture Toughness
 - 5.3.1.6 Material Surveillance

- 5.3.1.7 Regulatory Guide 1.65
- 5.3.2 Pressure/Temperature Limits
 - 5.3.2.1 Limit Curves
 - 5.3.2.2 Operating Procedures
- 5.3.3 Reactor Vessel Integrity
 - 5.3.3.1 Design Bases
 - 5.3.3.2 Description
 - 5.3.3.3 Materials of Construction
 - 5.3.3.4 Inspection Requirements
 - 5.3.3.5 Shipment and Installation
 - 5.3.3.6 Operating Conditions
 - 5.3.3.7 In-service Surveillance
- 5.3.4 COL Information
- 5.3.5 References

5.4 Component and Subsystem Design

- 5.4.1 Reactor Recirculation System
 - 5.4.1.1 Pump Flywheel Integrity (PWR)
- 5.4.2 Steam Generators (PWR)
- 5.4.3 Reactor Coolant Piping
- 5.4.4 Main Steamline Flow Restrictors
- 5.4.5 Main Steamline Isolation System
- 5.4.6 Isolation Condenser System (ICS)
- 5.4.7 Residual Heat Removal System
- 5.4.8 Reactor Water Cleanup/Shutdown Cooling System
- 5.4.9 Main Steamlines and Feedwater Piping
- 5.4.10 Pressurizer
- 5.4.11 Pressurizer Relief Discharge System
- 5.4.12 Reactor Coolant System High Point Vents
- 5.4.13 Safety/Relief Valves
- 5.4.14 Component Supports
 - 5.4.14.3 Safety Evaluation
- 5.4.15 COL Information
- 5.4.16 References

6. Engineered Safety Features

6.0 General

6.1 Engineered Safety Feature Materials

6.1.1 Metallic Materials

6.1.2 Organic Materials

6.1.3 COL Information

6.2 Containment Systems

6.2.1 Containment Functional Design

6.2.2 Passive Containment Cooling System

6.2.3 Reactor Building Functional Design

6.2.4 Containment Isolation Function

6.2.5 Combustible Gas Control in Containment

6.2.6 Containment Leakage Testing

6.2.7 Fracture Prevention of Containment Pressure Boundary

6.2.8 COL Information

6.2.9 References

6.3 Emergency Core Cooling Systems

6.3.1 Design Bases and Summary Description

6.3.2 System Design

6.3.3 ECCS Performance Evaluation

6.3.4 ECCS Performance Tests

6.3.5 Instrumentation Requirements

6.3.6 COL Information

6.3.7 References

6.4 Control Room Habitability Systems

6.4.1 Design Bases

6.4.2 System Design

6.4.3 Control Room Habitability Area

6.4.4 System Operation Procedures

6.4.5 Design Evaluations

6.4.6 Life Support

6.4.7 Testing and Inspection

6.4.8 Instrumentation Requirements

6.4.9 COL Information

6.5 Atmosphere Cleanup Systems

6.5.1 Containment Spray Systems

6.5.2 Fission Product Control Systems and Structures

6.5.3 Ice Condenser as a Fission Product Control System

6.5.4 Suppression Pool as a Fission Product Cleanup System

6.5.5 COL Information

6.6 Preservice and Inservice Inspection and Testing of Class 2 and 3 Components and Piping

- 6.6.1 Class 2 and 3 System Boundaries
- 6.6.2 Accessibility
- 6.6.3 Examination Categories and Methods
- 6.6.4 Inspection Intervals
- 6.6.5 Evaluation of Examination Results
- 6.6.6 System Pressure Tests
- 6.6.7 Augmented Inservice Inspections
- 6.6.8 Code Exemptions
- 6.6.9 Code Cases
- 6.6.10 Plant Specific PSI/ISI Program Information
- 6.6.11 COL Information

7. Instrumentation And Control Systems

7.1 Introduction

- 7.1.1 Identification of I&C Systems
 - 7.1.1.1 General
 - 7.1.1.2 The ESBWR Instrumentation and Control Architecture
 - 7.1.1.3 Reactor Trip System
 - 7.1.1.4 Engineered Safety Features Systems
 - 7.1.1.5 Safety and Non-Safety Shutdown Systems
 - 7.1.1.6 Safety-Related Information Systems
 - 7.1.1.7 Interlock Systems
 - 7.1.1.8 Control Systems
 - 7.1.1.9 Diverse Instrumentation and Controls
 - 7.1.1.10 Data Communication Systems
- 7.1.2 Identification of Design Bases and Safety Criteria
- 7.1.3 COL Information
- 7.1.4 References

7.2 Reactor Trip System

- 7.2.1 Reactor Protection System
- 7.2.2 Neutron Monitoring System
- 7.2.3 Suppression Pool Temperature Monitoring
- 7.2.4 COL Information
- 7.2.5 References

7.3 Engineered Safety Features Systems

- 7.3.1 Emergency Core Cooling System
 - 7.3.1.1 Automatic Depressurization System (ADS) Function
 - 7.3.1.2 Gravity-Driven Cooling System
- 7.3.2 Passive Containment Cooling System
- 7.3.3 Leak Detection and Isolation System
- 7.3.4 Safety System Logic and Control
- 7.3.5 COL Information
- 7.3.6 References

7.4 Safety-Related and Nonsafety-Related Shutdown Systems

- 7.4.1 Standby Liquid Control System
- 7.4.2 Remote Shutdown System
- 7.4.3 Reactor Water Cleanup/Shutdown Cooling System
- 7.4.4 Isolation Condenser System
- 7.4.5 COL Information
- 7.4.6 References

7.5 Safety-Related And Nonsafety-Related Information Systems

- 7.5.1 General I&C Conformance to Regulatory Guide 1.97
 - 7.5.1.1 System Descriptions

- 7.5.1.2 Post-Accident Monitoring System
- 7.5.1.3 Systems Analysis - Post-Accident Monitoring System
- 7.5.2 Containment Monitoring System
- 7.5.3 Process Radiation Monitoring System
- 7.5.4 Area Radiation Monitoring System
- 7.5.5 Pool Monitoring Subsystems
 - 7.5.5.1 General Functional Requirements Conformance
 - 7.5.5.2 Suppression Pool
 - 7.5.5.3 GDCS Pools
 - 7.5.5.4 IC/PCC Pools
 - 7.5.5.5 Spent Fuel Pool
- 7.5.6 Wetwell-to-Drywell Vacuum Breaker Monitoring
- 7.5.7 COL Information
- 7.5.8 References

7.6 Interlock Systems

- 7.6.1 HP/LP System Interlock Function
- 7.6.2 Other Interlocks
- 7.6.3 COL Information
- 7.6.4 References

7.7 Control Systems

- 7.7.1 Nuclear Boiler System
- 7.7.2 Rod Control and Information System
- 7.7.3 Feedwater Control System
- 7.7.4 Plant Automation System
- 7.7.5 Steam Bypass and Pressure Control System
- 7.7.6 Neutron Monitoring System - Nonsafety-Related Subsystems
- 7.7.7 Containment Inerting System
- 7.7.8 COL Information
- 7.7.9 References

7.8 Diverse Instrumentation and Control Systems

- 7.8.1 System Description
 - 7.8.1.1 ATWS Mitigation Functions
 - 7.8.1.2 Diverse Instrumentation and Control
 - 7.8.1.3 Diverse Manual Controls and Displays
- 7.8.2 Common Mode Failure Defenses within Safety System Design
 - 7.8.2.1 Design Techniques for Optimizing Safety-Related Hardware and Software
 - 7.8.2.2 System Defense against Common Mode Failure
- 7.8.3 Specific Regulatory Requirements Conformance
- 7.8.4 COL Information
- 7.8.5 References

7.9 Data Communication Systems

- 7.9.1 Essential Distributed Control and Information System (E-DCIS)

7.9.2 Non-Essential - Distributed Control and Information System (NE-DCIS)

Appendix 7A Fixed In-Core Calibration System for the Neutron Monitoring System

7A.1 Introduction

7A.1.1 Objectives

7A.1.2 Principles of the Gamma Thermometer

7A.1.3 Summary of Gamma Thermometer Application in All BWRs

7A.2 Gamma Thermometer System Definition

7A.2.1 Hardware Description

7A.2.2 Software Description

7A.3 Gamma Thermometer System Functions

7A.3.1 LPRM Calibration

7A.3.2 Core Monitoring with Gamma Thermometers

7A.4 Prior Experience with Gamma Thermometers

7A.4.1 Nuclear Industry Experience

7A.4.2 BWR Experience

7A.5 Uncertainty Analysis

7A.5.1 GT Adaptive Core Monitoring Accuracy

7A.5.2 Estimated Bundle Power Uncertainty

7A.6 Conclusions

7A.7 References

Appendix 7B Software Quality Program for Hardware/Software Design and Development

7B.1 Software Quality Assurance Program

7B.2 Software Management Plan

7B.3 Software Development Project Plan

7B.4 Software Configuration management plan

7B.5 Verification and Validation Plan

7B.6 Software Safety Plan

7B.7 Software Test Plan

7B.8 Operational and Maintenance Plans (O&M Manual)

7B.9 Training Plan

7B.10 Integration Plan

7B.11 Installation Plan

7B.12 References

8. Electric Power

8.1 Introduction

- 8.1.1 General
- 8.1.2 Utility Power Grid and Off-site Systems Description
- 8.1.3 On-site Electric Power System
- 8.1.4 Safety-Related Loads
- 8.1.5 Design Basis
- 8.1.6 COL Information
- 8.1.7 References

8.2 Off-site Power Systems

- 8.2.1 Description
- 8.2.2 Analysis
- 8.2.3 Design Bases (Interface Requirements)
- 8.2.4 COL Information
- 8.2.5 References

8.3 On-site Power Systems

- 8.3.1 AC Power Systems
- 8.3.2 DC Power Systems
- 8.3.3 Fire Protection of Cable Systems
- 8.3.4 COL Information
- 8.3.5 Additional Industry Standards
- 8.3.6 References

Appendix 8A Miscellaneous Electrical Systems

- 8A.1 Station Grounding and Surge Protection
 - 8A.1.1 Description
 - 8A.1.2 Analysis
 - 8A.1.3 COL Information
- 8A.2 Cathodic Protection
 - 8A.2.1 Description
 - 8A.2.2 Analysis
 - 8A.2.3 COL Information
- 8A.3 Electric Heat Tracing
 - 8A.3.1 Description
 - 8A.3.2 Analysis
 - 8A.3.3 COL Information
- 8A.4 References

Appendix 8B Realistic Station Blackout Evaluation

- 8B.1 Introduction
- 8B.2 Acceptance Criteria
- 8B.3 Analysis Assumptions
- 8B.4 Analysis Results

9. Auxiliary Systems

9.1 Fuel Storage and Handling

- 9.1.1 New Fuel Storage
- 9.1.2 Spent Fuel Storage
- 9.1.3 Fuel and Auxiliary Pools Cooling System
- 9.1.4 Light Load Handling System (Related to Refueling)
- 9.1.5 Overhead Heavy Load Handling Systems (OHLHS)
- 9.1.6 COL Information
- 9.1.7 References

9.2 Water Systems

- 9.2.1 Plant Service Water System
- 9.2.2 Reactor Component Cooling Water System
- 9.2.3 Makeup Water System
- 9.2.4 Potable and Sanitary Water Systems
- 9.2.5 Ultimate Heat Sink
- 9.2.6 Condensate Storage and Transfer System
- 9.2.7 Chilled Water System
- 9.2.8 Turbine Component Cooling Water System
- 9.2.9 COL Information
- 9.2.10 References

9.3 Process Auxiliaries

- 9.3.1 Compressed Air Systems
- 9.3.2 Process Sampling System
- 9.3.3 Equipment and Floor Drain System
- 9.3.4 Chemical and Volume Control System
- 9.3.5 Standby Liquid Control System
- 9.3.6 Instrument Air System
- 9.3.7 Service Air System
- 9.3.8 High Pressure Nitrogen Supply System
- 9.3.9 Hydrogen Water Chemistry System
- 9.3.10 Oxygen Injection System
- 9.3.11 Zinc Injection System
- 9.3.12 Auxiliary Boiler System
- 9.3.13 COL Information
- 9.3.14 References

9.4 Air Conditioning, Heating, Cooling, and Ventilation

- 9.4.1 Control Room Area Ventilation System
- 9.4.2 Fuel Building HVAC System (FBHVS)
- 9.4.3 Radwaste Building Heating, Ventilation and Air Conditioning System
- 9.4.4 Turbine Building HVAC System
- 9.4.5 Engineered Safety Feature Ventilation System
- 9.4.6 Reactor Building HVAC System

9.4.7 Electrical Building HVAC System

9.4.8 Drywell Cooling System

9.4.9 Containment Inerting System

9.4.10 COL Information

9.4.11 References

9.5 Other Auxiliary Systems

9.5.1 Fire Protection System

9.5.2 Communications Systems

9.5.3 Lighting System

9.5.4 Diesel Generator Fuel Oil Storage and Transfer System

9.5.5 Diesel Generator Jacket Cooling Water System

9.5.6 Diesel Generator Starting Air System

9.5.7 Diesel Generator Lubrication System

9.5.8 Diesel Generator Combustion Air Intake and Exhaust System

9.5.9 COL Information

9.5.10 References

Appendix 9A. Fire Hazards Analysis

9A.1 Introduction

9A.2 Analysis Criteria

9A.2.1 Codes and Standards

9A.2.2 Fire Area Separation and Fire Equipment Drawings

9A.2.3 Terminology

9A.2.4 Acceptance Criteria

9A.2.5 Systems Required to Achieve Safe Shutdown in the Event of Fire

9A.2.6 Redundant Nonsafety Systems and Equipment

9A.3 Analysis Approach

9A.3.1 Review Data

9A.3.2 Steam Tunnel Barrier Exception

9A.3.3 Exceptions to Separation Criteria

9A.3.4 Exceptions to Penetration Requirements

9A.3.5 Wall Deviations

9A.3.6 Door Deviations

9A.3.7 Basemats

9A.3.8 Smoke Removal

9A.4 Fire Hazard and Safe Shutdown Analysis Summary

9A.4.1 Reactor Building

9A.4.2 Fuel Building

9A.4.3 Control Building

9A.4.4 Turbine Building

9A.4.5 Radwaste Building

9A.4.6 Electrical Building

9A.4.7 Yard

9A.4.8 Service Building

9A.4.9 Service Water/Water Treatment Building

9A.5 Fire Protection Analyses by Room or Fire Zone

9A.5.1 Reactor Building

9A.5.2 Fuel Building

9A.5.3 Control Building

9A.5.4 Turbine Building

9A.5.5 Radwaste Building

9A.5.6 Electrical Building

9A.5.7 Yard

9A.5.8 Service Building

9A.5.9 Service Water/Water Treatment Building

9A.6 Special Cases

9A.6.1 Piping Penetrations, Reactor Building

9A.6.2 Fire Door Deviations

9A.6.3 Pipe Break Analyses

9A.6.4 Fire Separation for Divisional Electrical Systems

9A.6.5 Comparison to BTP SBLP 9.5-1 and Regulatory Guide 1.189

9A.6.6 Comparison to International Building Code

9A.7 COL Information

Appendix 9B Summary Of Analysis Supporting Fire Protection Design Requirements

9B.1 Introduction

9B.2 Fire Containment System

9B.3 Fire Types

9B.4 Fire Barriers

9B.5 Allowable Combustible Loading

9B.5.1 Permanent Loading

9B.5.2 Transient Combustibles

9B.5.3 Cable Trays

9B.6 References

10. Steam and Power Conversion System

10.1 Summary Description

- 10.1.1 Protective Features
- 10.1.2 COL Information
- 10.1.3 References

10.2 Turbine Generator

- 10.2.1 Design Bases
- 10.2.2 Description
- 10.2.3 Turbine Integrity
- 10.2.4 Evaluation
- 10.2.5 COL Information
- 10.2.6 References

10.3 Turbine Main Steam System

- 10.3.1 Design Bases
- 10.3.2 Description
- 10.3.3 Evaluation
- 10.3.4 Inspection and Testing Requirements
- 10.3.5 Water Chemistry (PWR)
- 10.3.6 Steam and Feedwater System Materials
- 10.3.7 COL Information
- 10.3.8 References

10.4 Other Features of Steam and Power Conversion System

- 10.4.1 Main Condenser
- 10.4.2 Condenser Air Removal System
- 10.4.3 Turbine Gland Seal System
- 10.4.4 Turbine Bypass System
- 10.4.5 Circulating Water System
- 10.4.6 Condensate Purification System
- 10.4.7 Condensate and Feedwater System
- 10.4.8 Steam Generator Blowdown System (PWR)
- 10.4.9 Auxiliary Feedwater System (PWR)
- 10.4.10 COL Information

Appendix 10A. Alternative design for Steam and Power Conversion System

10A.1 Abstract

- 10A.1.1 Protective Features
- 10A.1.2 COL Information
- 10A.1.3 References

10A.2 Turbine Generator

- 10A.2.1 Design Bases

10A.2.2 Description
10A.2.3 Turbine Integrity
10A.2.4 Evaluation
10A.2.5 COL Information
10A.2.6 References

10A.3 Turbine Main Steam System

10A.3.1 Design Bases
10A.3.2 Description
10A.3.3 Evaluation
10A.3.4 Inspection and Testing Requirements
10A.3.5 Water Chemistry (PWR)
10A.3.6 Steam and Feedwater System Materials
10A.3.7 COL Information
10A.3.8 References

10A.4 Other Features of Steam and Power Conversion System

10A.4.1 Main Condenser
10A.4.2 Condenser Air Removal System
10A.4.3 Turbine Gland Seal System
10A.4.4 Turbine Bypass System
10A.4.5 Circulating Water System
10A.4.6 Condensate Purification System
10A.4.7 Condensate and Feedwater System
10A.4.8 Steam Generator Blow Down System (PWR)
10A.4.9 Auxiliary Feedwater System (PWR)
10A.4.10 COL Information

10A.5 Turbine Building Simplified General Arrangement Drawings

11. Radioactive Waste Management

11.1 SOURCE TERMS

- 11.1.1 Fission Products
- 11.1.2 Activation Products
- 11.1.3 Radionuclide Concentration Adjustment
- 11.1.4 Fuel Fission Production Inventory
- 11.1.5 Process Leakage Sources
- 11.1.6 References

11.2 LIQUID WASTE MANAGEMENT SYSTEM

- 11.2.1 Design Bases
- 11.2.2 System Description
- 11.2.3 Safety Evaluation — Radioactive Releases
- 11.2.4 Testing and Inspection Requirements
- 11.2.5 Instrumentation Requirements
- 11.2.6 COL Information
- 11.2.7 References

11.3 GASEOUS WASTE MANAGEMENT SYSTEM

- 11.3.1 Design Bases
- 11.3.2 Offgas System Description
- 11.3.3 Ventilation System
- 11.3.4 Radioactive Releases
- 11.3.5 Testing and Inspection Requirements
- 11.3.6 Instrumentation Requirements
- 11.3.7 Radioactive OffGas System Leak or Failure
- 11.3.8 COL Information
- 11.3.9 References

11.4 SOLID WASTE MANAGEMENT SYSTEM

- 11.4.1 Design Bases
- 11.4.2 System Description
- 11.4.3 Safety Evaluation
- 11.4.4 Testing and Inspection Requirements
- 11.4.5 Instrumentation Requirements
- 11.4.6 COL Information
- 11.4.7 References

11.5 PROCESS RADIATION MONITORING SYSTEM

- 11.5.1 Design Bases
- 11.5.2 System Design Bases and Criteria
- 11.5.3 Subsystem Description
- 11.5.4 Regulatory Evaluation
- 11.5.5 Process Monitoring and Sampling
- 11.5.6 Calibration and Maintenance

11.5.7 COL Information
11.5.8 References

12. Radiation Protection

12.1 Ensuring That Occupational Radiation Exposures Are ALARA

- 12.1.1 Policy Considerations
- 12.1.2 Design Considerations
- 12.1.3 Operational Considerations
- 12.1.4 COL Information
- 12.1.5 References

12.2 Plant Sources

- 12.2.1 Contained Sources
- 12.2.2 Airborne and Liquid Sources for Environmental Consideration
- 12.2.3 COL Information
- 12.2.4 References

12.3 Radiation Protection

- 12.3.1 Facility Design Features
- 12.3.2 Shielding
- 12.3.3 Ventilation
- 12.3.4 Area Radiation and Airborne Radioactivity Monitoring Instrumentation
- 12.3.5 Post-Accident Access Requirements
- 12.3.6 Post-Accident Radiation Zone Maps
- 12.3.7 COL Information
- 12.3.8 References

12.4 Dose Assessment

- 12.4.1 Drywell Dose
- 12.4.2 Reactor Building Dose
- 12.4.3 Fuel Building Dose
- 12.4.4 Turbine Building Dose
- 12.4.5 Radwaste Building Dose
- 12.4.6 Work at Power Doses
- 12.4.7 COL Information
- 12.4.8 References

12.5 Operational Radiation Protection Program

- 12.5.1 Objectives
- 12.5.2 Equipment, Instrumentation, and Facilities
- 12.5.3 Operational Considerations
- 12.5.4 COL Information
- 12.5.5 References

12.6 Minimization of Contamination and radwaste generation

- 12.6.1 Minimization of Contamination to Facilitate Decommissioning
- 12.6.2 Minimization of Radioactive Waste Generation
- 12.6.3 COL Information

12.6.4 References

Appendix 12A Calculation of Airborne Radionuclides

12A.1 Evaluation Parameters

12A.2 Example Calculation

12A.3 COL Information

12A.4 References

13. CONDUCT OF OPERATIONS

13.1 Organizational Structure Of Applicant

13.1.1 COL Information

13.2 Training

13.2.1 Reactor Operator Training

13.2.2 Training for Non-Licensed Plant Staff

13.2.3 COL Information

13.3 Emergency Planning

13.3.1 Preliminary Planning

13.3.2 Emergency Plan

13.3.3 COL License Information

13.4 Review And Audit

13.4.1 COL Information

13.5 Plant Procedures

13.5.1 Administrative Procedures

13.5.2 Operating and Maintenance Procedures

13.5.3 COL Information

13.5.4 References

13.6 Physical Security

13.6.1 Preliminary Planning

14. Initial Test Program

14.1 Initial Test Program For Preliminary Safety Analysis Reports

14.2 Initial Plant Test Program For Final Safety Analysis Reports

14.2.1 Summary of Test Program and Objectives

14.2.2 Test Procedures

14.2.3 Test Program's Conformance with Regulatory Guides

14.2.4 Utilization of Reactor Operating and Testing Experience in the Development of Test Program

14.2.5 Use of Plant Operating and Emergency Procedures

14.2.6 Initial Fuel Loading and Initial Criticality

14.2.7 Test Program Schedule and Sequence

14.2.8 Individual Test Descriptions

14.2.9 COL Information

14.2.10 References

14.3 Selection Of Tier 1 Criteria and Processes

14.3.1 Tier 1, Section 1 - Introduction

14.3.2 Tier 1, Section 2 - Design Descriptions and ITAACs

14.3.3 Tier 1, Section 3 - Non-System Based Material

14.3.4 Tier 1, Section 4 - Interface Material

14.3.5 Tier 1, Section 5 - Site Parameters

14.3.6 Summary

15. Safety Analyses

15.0 Analytical Approach

- 15.0.1 Classification and Selection of Events
- 15.0.2 Abnormal Events To Be Evaluated
- 15.0.3 Determination of Safety Analysis Acceptance Criteria
 - 15.0.3.1 Anticipated Operational Occurrences
 - 15.0.3.2 Infrequent Events
 - 15.0.3.3 Accidents
 - 15.0.3.4 Special Events
- 15.0.4 Event Analysis Format
- 15.0.5 Single Failure Criterion
- 15.0.6 References

15.1 Nuclear Safety Operational Analysis

- 15.1.1 Analytical Approach
- 15.1.2 Method of Analysis
- 15.1.3 NSOA Results
- 15.1.4 Event Evaluations

15.2 Analysis of Anticipated Operational Occurrences

- 15.2.1 Decrease In Core Coolant Temperature
 - 15.2.1.1 Loss Of Feedwater Heating
- 15.2.2 Increase In Reactor Pressure
 - 15.2.2.1 Closure of One Turbine Control Valve
 - 15.2.2.2 Generator Load Rejection With Turbine Bypass
 - 15.2.2.3 Generator Load Rejection With a Single Failure in the Turbine Bypass System
 - 15.2.2.4 Turbine Trip With Turbine Bypass
 - 15.2.2.5 Turbine Trip With a Single Failure in the Turbine Bypass System
 - 15.2.2.6 Closure of One Main Steamline Isolation Valve
 - 15.2.2.7 Closure of All Main Steamline Isolation Valves
 - 15.2.2.8 Loss of Condenser Vacuum
 - 15.2.2.9 Loss of Shutdown Cooling Function of RWCU/SDC
- 15.2.3 Reactivity and Power Distribution Anomalies
- 15.2.4 Increase in Reactor Coolant Inventory
 - 15.2.4.1 Inadvertent Isolation Condenser Initiation
 - 15.2.4.2 Runout of One Feedwater Pump
- 15.2.5 Decrease in Reactor Coolant Inventory
 - 15.2.5.1 Opening of One Turbine Control or Bypass Valve.
 - 15.2.5.2 Loss of Non-Emergency AC Power to Station Auxiliaries
 - 15.2.5.3 Loss of All Feedwater Flow
- 15.2.6 AOO Analysis Summary
- 15.2.7 COL Information

15.2.8 References

15.3 Analysis Of Infrequent Events

- 15.3.1 Loss Of Feedwater Heating With Failure of Selected Control Rod Run-In
- 15.3.2 Feedwater Controller Failure – Maximum Demand
- 15.3.3 Pressure Regulator Failure – Opening of All Turbine Control and Bypass Valves
- 15.3.4 Pressure Regulator Failure–Closure of All Turbine Control and Bypass Valves
- 15.3.5 Generator Load Rejection With Total Turbine Bypass Failure
- 15.3.6 Turbine Trip With Total Turbine Bypass Failure
- 15.3.7 Control Rod Withdrawal Error During Refueling
- 15.3.8 Control Rod Withdrawal Error During Startup
- 15.3.9 Control Rod Withdrawal Error During Power Operation
- 15.3.10 Fuel Assembly Loading Error, Mislocated Bundle
- 15.3.11 Fuel Assembly Loading Error, Misoriented Bundle
- 15.3.12 Inadvertent SDC Function Operation
- 15.3.13 Inadvertent Opening of a Safety-Relief Valve
- 15.3.14 Inadvertent Opening of a Depressurization Valve
- 15.3.15 Stuck Open Safety-Relief Valve
- 15.3.16 Liquid Containing Tank Failure
- 15.3.17 COL Information
- 15.3.18 References

15.4 Analysis of Accidents

- 15.4.1 Fuel Handling Accident
- 15.4.2 Loss-of-Coolant Accident Containment Analysis
- 15.4.3 Loss-of-Coolant Accident ECCS Performance Analysis
- 15.4.4 Loss-of-Coolant Accident Inside Containment Radiological Analysis
- 15.4.5 Main Steamline Break Accident Outside Containment
- 15.4.6 Control Rod Drop Accident
- 15.4.7 Feedwater Line Break Outside Containment
- 15.4.8 Failure of Small Line Carrying Primary Coolant Outside Containment
- 15.4.9 RWCU/SDC System Line Failure Outside Containment
- 15.4.10 Spent Fuel Cask Drop Accident
- 15.4.11 COL Information
- 15.4.12 References

15.5 Special Event Evaluations

- 15.5.1 Overpressure Protection
- 15.5.2 Shutdown Without Control Rods (Standby Liquid Control System Capability)
- 15.5.3 Shutdown from Outside Main Control Room
- 15.5.4 Anticipated Transients Without Scram
- 15.5.5 Station Blackout
- 15.5.6 Safe Shutdown Fire
- 15.5.7 Waste Gas System Leak or Failure
- 15.5.8 References

Appendix 15A Event Frequency Determination

15A.1 Scope

15A.2 Methodology

15A.3 Results

15A.3.1 Pressure Regulator Failure – Opening of All Turbine Control and Bypass Valves

15A.3.2 Pressure Regulator Failure – Closure of All Turbine Control and Bypass Valves

15A.3.3 Turbine Trip with Total Bypass Failure

15A.3.4 Generator Load Rejection with Total Turbine Bypass Failure

15A.3.5 Feedwater Controller Failure - Maximum Demand

15A.3.6 Loss of Feedwater Heating with Failure of Selected Control Rod Run-In

15A.3.7 Inadvertent Shutdown Cooling Function Operation

15A.3.8 Inadvertent Opening of a Safety/Relief Valve

15A.3.9 Inadvertent Opening of a Depressurization Valve

15A.3.10 Stuck Open Relief Valve

15A.3.11 Control Rod Withdrawal Error During Refueling

15A.3.12 Control Rod Withdrawal Error During Startup

15A.3.13 Control Rod Withdrawal Error During Power Operation

15A.3.14 Fuel Assembly Loading Error, Mislocated Bundle

15A.3.15 Fuel Assembly Loading Error, Misoriented Bundle

15A.3.16 Liquid-Containing Tank Failure

15A.4 Summary

15A.5 References

Appendix 15B LOCA Inventory Curves

16. Technical Specifications

1.0 Use And Application

2.0 Safety Limits (SLs)

3.0 Limiting Conditions for Operation (LCOs) Applicability and Surveillance Requirements (SR) Applicability

- 3.1 Reactivity Control Systems
- 3.2 Power Distribution Limits
- 3.3 Instrumentation
- 3.4 Reactor Coolant System (RCS)
- 3.5 Emergency Core Cooling Systems (ECCS)
- 3.6 Containment Systems
- 3.7 Plant Systems
- 3.8 Electrical Power Systems
- 3.9 Refueling Operations
- 3.10 Special Operations

4.0 Design Features

5.0 Administrative Controls

16B. Bases

B2.0 Safety Limits (SLs)

B3.0 Limiting Conditions for Operation (LCOs) Applicability and Surveillance Requirements (SR) Applicability

- B3.1 Reactivity Control Systems
- B3.2 Power Distribution Limits
- B3.3 Instrumentation
- B3.4 Reactor Coolant System (RCS)
- B3.5 Emergency Core Cooling Systems (ECCS)
- B3.6 Containment Systems
- B3.7 Plant Systems
- B3.8 Electrical Power Systems
- B3.9 Refueling Operations
- B3.10 Special Operations

17. Quality Assurance

17.0 Introduction

17.1 Quality Assurance During Design and Construction

- 17.1.1 Organization
- 17.1.2 Quality Assurance Program
- 17.1.3 Design Control
- 17.1.4 Procurement Document Control
- 17.1.5 Instruction, Procedures, and Drawings
- 17.1.6 Document Control
- 17.1.7 Control of Purchased Material, Equipment, and Services
- 17.1.8 Identification and Control of Materials, Parts, and Components
- 17.1.9 Control of Special Processes
- 17.1.10 Inspection
- 17.1.11 Test Control
- 17.1.12 Control of Measuring and Test Equipment
- 17.1.13 Handling, Storage, and Shipping
- 17.1.14 Inspection, Test, and Operating Status
- 17.1.15 Nonconforming Materials, Parts, or Components
- 17.1.16 Corrective Action
- 17.1.17 Quality Assurance Records
- 17.1.18 Audits
- 17.1.19 References

17.2 Quality Assurance During the Operations Phase

17.3 Quality Assurance Program Document

17.4 Reliability Assurance Program During Design Phase

- 17.4.1 Introduction
- 17.4.2 Scope
- 17.4.3 Purpose
- 17.4.4 Objective
- 17.4.5 GENE Organization for D RAP
- 17.4.6 SSC Identification/Prioritization
- 17.4.7 Design Considerations
- 17.4.8 Defining Failure Modes
- 17.4.9 Operational Reliability Assurance Activities
- 17.4.10 Owner/Operator's Reliability Assurance Program
- 17.4.11 D RAP Implementation
- 17.4.12 Glossary of Terms
- 17.4.13 COL Information
- 17.4.14 References

18. Human Factors Engineering

18.1 Overview

- 18.1.1 Reference
- 18.1.2 Design Goals and Design Bases
- 18.1.3 Planning, Development, and Design
- 18.1.4 Control Room Standard Design Features
- 18.1.5 Remote Shutdown System
- 18.1.6 Systems Integration
- 18.1.7 Detailed Design of the Operator Interface System
- 18.1.8 COL Information

18.2 HFE PROGRAM MANAGEMENT

- 18.2.1 The HFE Program and Implementation Plans
 - 18.2.2 Human Factors Engineering Program Plan
 - 18.2.3 HFE Design Team Composition
- ### **18.3 OPERATING EXPERIENCE REVIEW**

18.4 FUNCTIONAL REQUIREMENTS ANALYSIS AND FUNCTION ALLOCATION

- 18.4.1 System Functional Requirements Analysis Implementation Plan
- 18.4.2 Allocation of Function Implementation Plan

18.5 TASK ANALYSIS

- 18.5.1 Task Analysis Implementation Plan

18.6 STAFFING AND QUALIFICATIONS

- 18.6.1 Background
- 18.6.2 ESBWR Baseline Staffing Assumptions
- 18.6.3 Staffing and Qualifications Plan

18.7 HUMAN RELIABILITY ANALYSIS

- 18.7.1 Purpose
- 18.7.2 HRA Requirements Development
- 18.7.3 Methodology

18.8 HUMAN-SYSTEM INTERFACE DESIGN

- 18.8.1 HSI Design Implementation Plan

18.9 PROCEDURE DEVELOPMENT

18.10 TRAINING PROGRAM DEVELOPMENT

- 18.10.1 Purpose
- 18.10.2 Elements for training program development

18.11 HUMAN FACTORS VERIFICATION AND VALIDATION

- 18.11.1 Human Factors Verification and Validation Implementation Plan

18.12 DESIGN IMPLEMENTATION

18.13 Human Performance Monitoring

18.13.1 Purpose

18.13.2 HPM Strategy Development

18.13.3 Elements of HPM process

18.14 Inventory of Controls and Instrumentation

18.14.1 Operator Interface Equipment Characterization

18.14.2 Control Room Arrangement

18.14.3 Main Control Console Configuration

18.14.4 Large Display Panel Configuration

18.14.5 Systems Integration

Appendix 18A Emergency Procedure and Severe Accident Guidelines

18A.1 Introduction

18A.2 Operator Cautions

18A.3 RPV Control EMERGENCY Procedure Guideline

18A.4 Primary Containment Control Emergency Procedure Guideline

18A.5 Reactor Building Control Emergency Procedure Guideline

18A.6 Radioactivity Release Control Emergency Procedure Guideline

18A.7 Contingency #1 Emergency RPV Depressurization

18A.8 Contingency #2 RPV Flooding

18A.9 Contingency #3 Level/Power Control

18A.10 RPV and Primary Containment Flooding Severe Accident Guideline

18A.11 Containment and Radioactivity Release Severe Accident Guideline

Appendix 18B ESBWR EPG/SAG Compared To Generic BWR EPG

18B.1 ESBWR Design Features Affecting the EPG/SAG

18B.1.1 ESBWR RPV and Related Features

18B.1.2 Isolation Condenser

18B.1.3 Emergency Core Cooling Systems

18B.1.4 ATWS Mitigation Systems

18B.1.5 Containment Features

18B.2 Major Difference Between ESBWR and BWROG EPG/SAG Rev. 2

18B.2.1 Level Control

18B.2.2 Steam Cooling and Alternate Level Control

18B.2.3 Emergency Depressurization

18B.3 Specific Differences Between ESBWR and BWROG EPG/SAG Rev. 2

Appendix 18C ESBWR EPG/SAG Input Data

18C.1 Introduction

18C.2 Input Parameters

18C.3 Calculation Results

Appendix 18D Operator Interface Equipment Characterization

- 18D.1 Control Room Arrangement
- 18D.2 Main Control Console Configuration
- 18D.3 Large Display Panel Configuration
- 18D.4 Systems Integration

Appendix 18E ESBWR Human-System Interface Design Implementation Process**Appendix 18F Emergency Operation Information and Controls****Appendix 18G Design Development and Validation Testing**

- 18G.1 Introduction
 - 18G.1.1 Design Development
 - 18G.1.2 Allocation of Functions
 - 18G.1.3 Operator Work Load
 - 18G.1.4 Other Areas of Interest
- 18G.2 Validation Testing
 - 18G.2.1 General

Appendix 18H Supporting Analysis for Emergency Operation Information and Controls

19. PRA And Severe Accidents (Rev. 0)

19.1 Introduction and Summary

19.1.1 Regulatory Requirements for PRA and Severe Accidents

19.1.2 NRC Safety Goals

19.1.3 Comparison against NRC Safety Goals

19.2 PRA Summary and Results

19.2.1 Internal Events Analysis

19.2.2 External Events Analysis

19.2.3 Shutdown Risk Analysis

19.2.4 Containment Performance Analysis

19.2.5 Offsite Consequences Analysis

19.2.6 References

19.3 Severe Accident Management

19.3.1 Overview of ESBWR Severe Accident Design Features

19.3.2 Overall Severe Accident Assessment Methodology

19.3.3 Direct Containment Heating (DCH)

19.3.4 Ex-Vessel Steam Explosions (EVE)

19.3.5 Basemat Melt Penetration (BMP)

19.3.6 Results and Conclusions

19.4 PRA Insights Affecting ESBWR Design

19.4.1 Introduction

19.4.2 Insights from Level 1 Internal Events Analysis

19.4.3 Insights from Seismic Analysis

19.4.4 Insights from Fire Analyses

19.4.5 Insights from Flooding Analyses

19.4.6 Suppression Pool Bypass and Ex-Containment LOCA Insights

19.4.7 Shutdown PRA Insights

19.4.8 Insights from Level 2 Severe Accident Analyses

19.4.9 Severe Accident Mitigation Design Alternatives

19.4.10 Summary and Conclusions

19.4.11 References

19.5 PRA-Based Reliability, Availability And Maintainability

19.5.1 General Approach

19.5.2 Important Structures, Systems and Components (Level 1)

19.5.3 Important Structures, Systems and Components (Level 2)

19.5.4 Important Structures, Systems and Components (Seismic)

19.5.5 Important Structures, Systems and Components (Fire)

19.5.6 Important Structures, Systems and Components (Flood)

19.5.7 Important Structures, Systems and Components (Shutdown)

19.5.8 Important Systems with Redundant Trains

19.5.9 Important Capabilities Outside the Control Room

19.5.10 Reliability and Maintenance Actions

19.6 Regulatory Treatment of Non-Safety Systems

19.6.1 Introduction and Background

19.6.2 Description of the RTNSS Process

19.6.3 Review of ESBWR Against Deterministic RTNSS Criteria

19.6.4 Review of ESBWR Against Probabilistic RTNSS Criteria

19.6.5 Results