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Vol. 2, Pt. 2

NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document

Evolutionary Plant Designs
Chapters 2-13

Project Number 669

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

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ABSTRACT

The Electric Power Research Institute (EPRI) is preparing a compendium of technical requirements, referred to as the "Advanced Light Water Reactor [ALWR] Utility Requirements Document," that is applicable to the design of an ALWR power plant. When completed, this document is intended to be a comprehensive statement of utility requirements for the design, construction, and performance of an ALWR power plant for the 1990s and beyond.

The Requirements Document consists of three volumes. Volume I, "ALWR Policy and Summary of Top-Tier Requirements," is a management-level synopsis of the Requirements Document, including the design objectives and philosophy, the overall physical configuration and features of a future nuclear plant design, and the steps necessary to take the proposed ALWR design criteria beyond the conceptual design state to a completed, functioning power plant. Volume II consists of 13 chapters and contains utility design requirements for an evolutionary nuclear power plant [approximately 1350 megawatts-electric (MWe)]. Volume III contains utility design requirements for nuclear plants for which passive features will be used in their designs (approximately 600 MWe).

The staff of the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, has prepared Volumes 1 and 2 (Parts 1 and 2) of its safety evaluation report (SER) to document the results of its review of Volumes I and II of the Requirements Document. Volume 1, "NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document - Program Summary," provides a discussion of the overall purpose and scope of the Requirements Document, the background of the staff's review, the review approach used by the staff, and a summary of the policy and technical issues raised by the staff during its review. Volume 2, "NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document - Evolutionary Plant Designs," gives the results of the staff's review of the 13 chapters of the Requirements Document for evolutionary plant designs. Volume 3, "NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Requirements Document - Passive Plant Designs," scheduled to be issued in September 1993, will give the results of the staff's review of the 13 chapters of the Requirements Document for passive plant designs. Preliminary drafts of Volumes 1 and 2 were forwarded to the Commission and the Advisory Committee on Reactor Safeguards (ACRS) on May 12, 1992.

In staff requirements memoranda (SRM), the Commission instructed the staff to provide an analysis detailing where the staff proposes departure from current regulations or where the staff is substantially supplementing or revising interpretive guidance applied to currently licensed LWRs. The staff considers these to be policy issues. Appendix B to Chapter 1 of Volume 2 of this report gives the staff's regulatory analysis of those issues identified for the evolutionary plant designs. These issues have been addressed in Commission papers SECY-90-016, "Evolutionary Light Water Reactor Certification Issues and Their Relationship to Current Regulatory Requirements"; SECY-91-078, "Chapter 11 of the Electric Power Research Institute's Requirements Document and

Additional Evolutionary Light Water Reactor Certification Issues"; and in draft Commission papers, "Issues Pertaining to Evolutionary and Passive Light Water Reactors and Their Relationship to Current Regulatory Requirements," and "Design Certification and Licensing Policy Issues Pertaining to Passive and Evolutionary Advanced Light Water Reactor Designs," that were issued on February 27 and July 6, 1992, respectively.

In SRM dated June 26, 1990, and April 1, 1991, the Commission provided its decisions on SECY-90-016 and SECY-91-078 as they apply to evolutionary designs. The Commission will be reviewing the basis for the approach that the staff is proposing for those issues discussed in the draft Commission papers of February 27 and July 6, 1992, and, accordingly, may at some future point in the review determine that such issues involve policy questions that the Commission may wish to consider. These issues are considered fundamental to agency decisions on the acceptability of the ALWR designs. The staff will ensure satisfactory implementation of Commission guidance regarding these matters during its review of individual applications for final design approval and design certification.

There are no open issues pertaining to the Requirements Document for evolutionary plant designs other than policy issues on which the staff has taken a position, but for which the Commission has not had the opportunity to provide guidance. These issues are summarized in Section 4 of Volume 1 and discussed in detail in this report.

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PREFACE

This safety evaluation report (SER) (Volume 2) documents the review by the U.S. Nuclear Regulatory Commission (NRC) staff of the 13 chapters of Volume II of the Electric Power Research Institute's (EPRI's) Advanced Light Water Reactor (ALWR) Utility Requirements Document (hereafter referred to as the "Evolutionary Requirements Document"). Volume 1, which contains the program summary of the NRC review of Volumes I, II, and III of the ALWR Utility Requirements Document, also contains the references cited and the abbreviations used in this SER.

Each chapter of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's requirements for the design of evolutionary plants. These requirements apply to boiling-water reactors (BWRs) and pressurized-water reactors (PWRs), which will be rated at approximately 1350 megawatts-electric.

The design criteria specified by EPRI are intended to ensure that EPRI's policy statements discussed in Volume I of the ALWR Utility Requirements Document are met. These policy statements are discussed in Section 1.3 of Volume 1 of this report. They include consideration of simplification, design margin, human factors, safety, regulatory stabilization, standardization, use of proven technology, maintainability, constructibility, quality assurance, economics, protection against sabotage, and environmental effects.

The format of each chapter of this SER follows that of the corresponding chapter of the Evolutionary Requirements Document as closely as possible. Unless otherwise noted, references to sections of the Evolutionary Requirements Document pertain to that chapter.

Outstanding Issues

During its review of the original version of the Evolutionary Requirements Document, the staff identified two types of issues for which additional information was required before the staff could reach a final conclusion. The staff considered these issues to be outstanding. These issues fell into one of two categories: (1) open issues that had to be resolved before the staff could complete its review of the Evolutionary Requirements Document or (2) confirmatory issues for which the staff would ensure that EPRI met its commitments to revise the Evolutionary Requirements Document.

There are no open issues remaining on the Requirements Document for evolutionary plant designs other than policy issues on which the staff has taken a position, but for which the Commission has not had the opportunity to provide guidance. To provide continuity of the review, both the open and confirmatory items identified in the DSERs and the remaining open policy issues are listed in Section 1.4 of each chapter.

Vendor- or Utility-Specific Items

During its review of the Evolutionary Requirements Document, the staff identified items that were inadequately addressed by EPRI or were issues that could not be addressed generically. These items will have to be resolved during the staff's review of a vendor- or utility-specific application (i.e., an application for final design approval and design certification (FDA/DC) or a combined construction permit and operating license (combined license). They are listed in Section 1.5 of each chapter.

As discussed in Section 1.2 of Volume 1 of this report, the Requirements Document has no legal or regulatory status and is not intended to demonstrate complete compliance with the Commission's regulations, regulatory guidance, or policies. It is not intended to be used as a basis for supporting FDA/DC for a specific design, nor is it to be used to substitute for any portion of the staff's review of future applications for FDA/DC. Specifically, satisfactory resolution of the items identified in Sections 1.4 and 1.5 of each chapter for a vendor- or utility-specific application will not, by itself, support a finding that the application complies with the Commission's regulatory requirements. The staff will perform a complete licensing review of these applications using NUREG-0800, "Standard Review Plan [SRP] for the Review of Safety Analysis Reports for Nuclear Power Plants," and other appropriate Commission guidance. Satisfactory resolution of the open policy issues and vendor- or utility-specific items constitutes only one portion of the staff's review.

Availability

Copies of this report are available for inspection at the NRC Public Document Room, 2120 L Street, N.W., Washington, DC 20555.

The NRC project managers for the staff's review of EPRI's ALWR Utility Requirements Document are J. H. Wilson and T. J. Kenyon. They may be contacted by calling (301) 504-1118 or by writing to: Associate Directorate for Advanced Reactors and License Renewal, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

CHAPTER 2, "POWER GENERATION SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 2, "Power Generation Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 2 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering; Bechtel Power Corporation; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Science Applications International Corporation; Westinghouse Electric Corporation; and EPRI.

On October 15, 1986, EPRI submitted the original version of Chapter 2 of the Evolutionary Requirements Document for staff review. By letters dated May 27 and June 12, 1987, the staff requested that EPRI supply additional information. EPRI provided the information in its response dated September 17, 1987. Topic papers in Appendix B of the original version of this chapter were relocated to Appendix B of Chapter 1.

On February 16, 1988, the staff issued its DSER for Chapter 2 of the Evolutionary Requirements Document. In August 1988, April 1989, and July 1990, the staff and EPRI met with the Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on Improved Light Water Reactors to discuss Chapter 2, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 2, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 2 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 2

Chapter 2 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the power generation systems. Although these requirements apply to BWRs and PWRs, which will be rated at approximately 1350 MWe, a plant rated at 1100 MWe with a six-flow turbine was used in establishing some requirements that are based, in part, on economic evaluations.

The key topics addressed in the Chapter 2 review include EPRI-proposed design requirements for

- main/extraction steam system
- feedwater and condensate system

- chemical addition system
- condensate makeup purification system
- auxiliary steam system

1.3 Policy Issues

During its review of Chapter 2 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 2 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) classification of power generation system components (2.1)
(2) clarification of guidance regarding valving and piping materials (2.2)

Confirmatory Issues

None

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All issues identified in the DSER for Chapter 2 have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.2.V-1 safety valve design (3.4)
E.2.V-2 attachment loads for safety and relief valves (3.4)
E.2.V-3 side stream condensate polisher (4.3)
E.2.V-4 condensate makeup system raw water pretreatment (6.4)

2 COMMON REQUIREMENTS

2.1 General Requirements

EPRI states that the design of systems covered by this chapter will comply with the overall requirements of Chapter 1 of the Evolutionary Requirements Document. These systems include the main/extraction steam, feedwater and condensate, chemical addition, condensate makeup purification, and auxiliary steam systems. Consequently, the resolution of any open issues identified in the DSER for Chapter 1 (e.g., the application of leak-before-break analyses) could result in associated changes in Chapter 2.

EPRI has modified Chapter 1 to provide guidance to the plant designer for classifying and designing safety-related portions of systems for seismic and environmental qualification. The staff evaluated the revised section and table in Chapter 1 (Section 4.3, "Classification Requirements," and Table 1.4-1, "Structural Codes and Standards for Structures, Systems and Equipment,"). In the DSER for Chapter 2, the staff concluded that the classification information was still insufficient and too general to provide adequate guidance to plant designers. It, therefore, recommended that, for each system listed in Chapter 2, the corresponding design code or standard be specified for the piping and equipment and that the schematic diagram for each system include the jurisdictional boundaries for the corresponding design codes and standards. The staff position on seismic and environmental qualification, stated in Section 4 of the DSER for Chapter 1, was also referenced. This was an open issue in the DSER for Chapter 2.

In a letter dated March 14, 1991, EPRI responded to this DSER open issue by stating that specification of design codes and standards would require a detailed design that was beyond the scope of the Evolutionary Requirements Document and, therefore, no changes would be made to Chapter 1. The staff agrees that the original concern expressed in the DSER for Chapter 2 requires a level of detail that is generally beyond that of Chapter 1 and, therefore, this DSER open issue is closed. However, this issue is closely related to an open issue in Chapter 3 of this report concerning the control of BWR main steamline isolation valve leakage, which EPRI identified as a plant optimization subject in Section 2.3.1 of Appendix B to Chapter 1. EPRI proposes a requirement to eliminate the BWR main steamline isolation valve leakage control system and to provide an alternative leakage pathway (i.e., the main steamline and the condenser) to the main condenser downstream of the isolation valves in the event of a loss-of-coolant accident. This issue is also related to EPRI requirements in Section 3.3.2 of Appendix B, Section 3.4.1.5 of Chapter 2, Section 5.3.3 of Chapter 3, and Section 3 of Chapter 13 and is discussed further in the corresponding sections of this report.

2.2 Specific Requirements

2.2.1 Valves

In Section 2.2.B of Chapter 2 of the original Evolutionary Requirements Document, EPRI provided substantial guidance to plant designers aimed at minimizing and simplifying the valving throughout the power generation systems. The staff did not find any discrepancies with respect to current licensing requirements; however, it did request clarification of several items in its comments on valving and piping materials (Section 2.2.C) and considered this to be an open issue in the DSER for Chapter 2. In the DSER, the staff determined that requirements pertaining to material embrittlement and surveillance of valves and pipes in Section 2.2 of Chapter 2 were inadequate. EPRI revised Section 2.2.2 to reference Section 5 of Chapter 1, which provides requirements pertaining to material embrittlement and surveillance. The staff concludes that the revised Section 2.2.2 is acceptable and this issue is closed.

Section 12.2 of Chapter 1 specifies valve and valve actuator requirements for the ALWR.

2.2.2 Materials

Section 5 of Chapter 1 specifies material requirements for the ALWR. In particular, Section 5.3.2 contains requirements specifically for the feedwater, steam, and condensate systems, including requirements to minimize use of copper alloys and to use corrosion/erosion-resistant materials (not carbon steel) for piping and components exposed to wet steam or flashing liquid flow. Sections 3 through 7 of Chapter 2 contain other specific requirements for materials in the feedwater, steam, condensate and chemical addition systems.

2.2.3 Instrumentation and Controls

The instrumentation and control equipment for the power generation systems will meet the requirements of Chapter 10 of the Evolutionary Requirements Document. Controls and displays and their location will be established by the analyses of functions also required by Chapter 10.

With respect to instrumentation and controls (I&C), Chapter 2 defines functional requirements that will affect their type, range, and location but notes that the actual design requirements are given in Chapter 10. The staff has, therefore, documented its review of the I&C requirements in Chapter 2 in Chapter 10 of this report.

3 MAIN/EXTRACTION STEAM SYSTEM

3.1 System Definition

Section 3.1.1 of Chapter 2 of the Evolutionary Requirements Document states that the main/extraction steam system will be designed to (1) transport main steam from the steam generator (for PWR) or main steam isolation valve (for BWR) to the high-pressure turbine and to the moisture separator reheater; (2) transport extraction steam from the high-pressure and low-pressure turbines to the feedwater heaters; (3) provide steam to the auxiliary steam system and the emergency feedwater system turbine-driven pumps (for PWR); (4) provide steam bypass capability via the turbine bypass system for startup, shutdown, and step-load reduction transients (for BWR); (5) provide steam bypass and relief capacity for normal operating conditions and off-normal transients (for PWR); (6) provide isolation of the main steamlines in case of a main steamline break (for PWR); and (7) provide steam to steam jet air ejectors and to gland seals, etc. For the PWR, the system will include main steam piping from steam generators to the main turbine, main steam isolation valves (MSIVs), extraction steam piping, turbine bypass system, moisture separator/reheater, safety valves, and power-operated relief valves. For the BWR, the system will include main steam piping downstream of the second MSIVs, extraction steam piping, turbine bypass system, and moisture separator/heater.

PWR System Boundaries

Section 3.1.2 of Chapter 2 defines the main/extraction steam system boundaries as consisting of the following for a PWR:

- main steam piping up to but not including the turbine stop valves
- hot reheat piping up to but not including the reheat stop valves
- extraction steam and cold reheat piping
- turbine bypass system
- moisture separator/reheater
- MSIVs
- safety valves
- power-operated relief valves

BWR System Boundaries

Section 3.1.2 of Chapter 2 defines the main/extraction steam system boundaries as consisting of the following for a BWR:

- main steam piping downstream of the second MSIV up to, but not including, the turbine stop valves
- hot reheat piping up to but not including the reheat stop valves
- extraction steam and cold reheat piping
- turbine bypass system
- moisture separator/heater

The BWR MSIVs are not included because they are addressed in Chapter 3 of the Evolutionary Requirements Document. EPRI's design requirements for the turbine-generator are provided in Chapter 13.

Interfaces

Section 3.1.3 of Chapter 2 lists the systems with which the main/extraction steam system will interface. That is, the BWR reactor coolant system (RCS) and PWR steam generator system (Chapter 3), turbine-generator system (Chapter 13), the emergency feedwater system turbine-driven pumps (Chapter 5), and the BWR radioactive waste drain system (Chapter 12).

3.2 Performance Requirements

Section 3.2 of Chapter 2 of the Evolutionary Requirements Document defines the performance requirements for steam bypass and relief capability, MSIVs, and MSIV bypass lines.

Section 3.2.1.1.3 of Chapter 2 states that all of the turbine bypass system flow will be directed to the condenser in order to conserve secondary water inventory. The staff is concerned about those times when the main condenser is not available. Applicants referencing the Evolutionary Requirements Document should consider allowing the release of noncontaminated steam through the steam bypass and relief system at settings below which the safety/relief valves operate. This procedure is consistent with the rationale of minimizing safety valve actuations and the conservation of secondary water inventory.

Section 3.2.1.3.1 of Chapter 2 states that for BWRs, the total flow capacity of the turbine bypass system will be 33 percent of the full turbine steam flow at full-load steam pressure.

For PWRs, Section 3.2.1.2.1 of Chapter 2 requires that the total flow capacity of the turbine bypass system be sufficient to eliminate challenges to the steam generator power-operated relief valves (PORVs) during reactor trip from full-power transient or turbine trips without reactor trip from 100-percent power. Section 3.3.2.2 further states that the maximum differential pressure between any two steam generator outlet nozzles should be less than 10 psi. The staff finds that these requirements for the PWR will minimize the difference between reactor coolant temperatures at the reactor inlet nozzles and are acceptable. Because the main steam piping will be designed so as to pass the full-rated flow of steam to the main turbine, it will have the capability to remove the residual heat from the reactor system in conformance with General Design Criterion (GDC) 34, "Residual Heat Removal," of 10 CFR Part 50.

Table 2.3-1 of Chapter 2 states that the MSIVs in a PWR will be fail-closed, bidirectional valves capable of stopping fully developed steamline break flows of both 100-percent and 4-percent steam within 5 seconds following receipt of a safety signal. The MSIVs will be environmentally qualified for both normal operating conditions and for the environment resulting from a steamline break. In the event of a main steamline break and a concurrent single active failure of one MSIV, the remaining isolation valves will close and limit the blowdown to the one steam generator with the broken steamline. The staff finds that the design requirements for the MSIVs in a PWR meet the requirements of GDC 57 and the staff's guidelines in SRP Section 6.2.4, "Containment Isolation System," and SRP Section 10.3, "Main Steam Supply System," and are acceptable.

However, Section 3.2.2 of Chapter 2 of the Evolutionary Requirements Document states that to meet the design requirements of the valves and actuators, the MSIV valve characteristics identified in Table 3-1 must be achieved. The staff notes that the cited table should be Table 2.3-1. For the BWR, the design requirements for the MSIVs and safety and relief valves are addressed in Chapter 3.

3.3 System Features

Section 3.3 of Chapter 2 of the Evolutionary Requirements Document defines requirements for system arrangement, system pressure drops and volumes, steam piping drains, and chemistry sampling connections.

3.4 Component Features

Section 3.4 of Chapter 2 defines the requirements for main/extraction steam system components.

Main Steamline Classification

Section 3.4.1.5 of Chapter 2 requires that the main steamline from the seismic restraint on the outboard side of the outermost main steam isolation valves up to and including the turbine main steam stop valves meet the requirements of seismic Category II. The staff identified this requirement as an open issue during its review of other chapters of the Evolutionary Requirements Document. The staff's evaluation and proposed resolution of this issue are provided in Section 2.3.1 of Appendix B to Chapter 1 of this report.

Extraction Steam and Cold Reheat Piping

Section 3.4.2.3 of Chapter 2 specifies that the extraction steam and cold reheat piping material will be of corrosion-resistant materials meeting the requirements of Section 5.3.2 of Chapter 1. Carbon steel must not be used.

The staff has also reviewed the materials requirements for extraction steam and cold reheat piping in Section 5.3.2 of Chapter 1 and concludes that they are acceptable, as documented in Section 5 of Chapter 1 of this report.

Safety Valves (PWR)

Section 3.4.3.2.2 of Chapter 2 states that the safety valves must be of a design proven to consistently open fully, at a pressure within acceptable limits around the set pressure, during operability tests. The design requirements and rationale for the safety valves are based on their functioning during operability tests. The staff concludes that these valves should also be able to function in harsh environments during emergencies when they will be needed to mitigate accidents. Therefore, applicants referencing the Evolutionary Requirements Document should base the safety valve design on accident conditions not operating conditions.

Safety and Relief Valves (PWR)

By letter dated May 17, 1991, the staff requested that Sections 3.4.3.2.4 and 3.4.3.3.3 of Chapter 2, which discuss attachment loads for PWR safety and relief valves, respectively, be revised to delete a reference to American

National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) B.31.1, Appendix 2, "Non-Mandatory Rules for the Design of Safety Valve Installations," and replace it with a requirement to design such installations in accordance with the acceptance criteria in Item II.2 of SRP Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures" (NUREG-0800). In Revision 3 of the Evolutionary Requirements Document, the reference to B.31.1 was deleted from both of the above sections in Chapter 2, but no reference to SRP Section 3.9.3 was made. However, Table B.1-2 in Appendix B to Chapter 1 of the Evolutionary Requirements Document commits to unconditional compliance of the ALWR to SRP Section 3.9.3. Therefore, the staff concludes that this is an acceptable commitment and will review individual applications for FDA/DC for both BWRs and PWRs against the guidance in Item II.2 of SRP Section 3.9.3.

<u>Moisture Separator/Reheaters</u>

Section 3.4.4.4 of Chapter 2 requires that corrosion/erosion-resistant materials meeting the requirements of Chapter 1, Section 5.3.2, be used for all components exposed to wet steam or flashing liquid flow where operating experience has shown that significant erosion could occur. In addition, Section 3.4.4.6 of Chapter 2 requires that reheater tube material be ferritic stainless steel.

The staff concludes that these requirements are acceptable because wet steam service has been a problem at operating power plants. Ferritic stainless steel tube material is corrosion/erosion resistant and is compatible with the intended service in both BWRs and PWRs.

3.5 Instrumentation and Controls

Section 3.5 of Chapter 2 of the Evolutionary Requirements Document requires instrumentation and control equipment for the main/extraction steam system, including

- heat balance instrumentation
- turbine bypass system valve interlocks and trips
- steamline break detection instrumentation (PWR)
- power-operated relief valves (PWR)
- main steam isolation valves (PWR)
- main steam isolation valve bypass valves (PWR)
- turbine main steam bypass valves
- main steamline drain pot drain valves
- moisture separator reheating steam cutoff, control, and purge valves
- heater extraction steamline isolation and power-assisted non-return valves

The staff's evaluation of the actual design requirements for this instrumentation and control equipment is provided in Chapter 10 of this report.

3.6 Maintenance

Section 3.6 of Chapter 2 refers to the general maintenance requirements in Chapter 1 of the Evolutionary Requirements Document. EPRI states that the requirements in Section 3.6 of Chapter 2 are intended to ensure that maintenance of all main steam system components can be accomplished quickly and safely. Section 3.6 of Chapter 2 requires that the following specific provisions be addressed during the design phase:

- adequate work space and ease of access to equipment and components
- adequate space and lifting provisions for removing valve components
- adequate space for laydown of equipment
- moisture separator/reheater pull fixtures specifically designed for each location
- physical layout to ensure safety of personnel during maintenance

The staff concludes that these requirements are acceptable because they represent reasonable provisions to address conditions that have hindered maintenance at operating power plants.

3.7 Conclusion

The staff concludes that, with the exception of the issues to be addressed by the applicant referencing the Evolutionary Requirements Document, as noted above, the design requirements in Chapter 2 of the Evolutionary Requirements Document for the main/extraction steam system are in general agreement with SRP Section 10.3 and are, therefore, acceptable.

4 FEEDWATER AND CONDENSATE SYSTEM

4.1 System Definition

The feedwater and condensate system will be designed to return high-quality feedwater from the condenser hotwell to the steam generators (for PWR) or reactor vessel (for BWR). Section 4.1.3 of Chapter 2 of the Evolutionary Requirements Document lists the systems with which the feedwater and condensate system will interface; one of the paragraphs states that the reactor coolant system will receive feedwater from the feedwater and condensate systems. The staff notes that this paragraph only applies to BWRs and should be so specified. Also, the feedwater and condensate system will interface with the auxiliary steam system (Section 7), auxiliary (emergency) feedwater system, and/or other engineered safety systems that are not listed.

4.2 Performance Requirements

Section 4.2 of Chapter 2 of the Evolutionary Requirements Document specifies that the feedwater and condensate system will have a number of stages for regenerative feedwater heating and provisions for maintaining feedwater quality. For the PWR, the system will include three condensate pumps with condensate polishers, three low-pressure feedwater heating trains with four feedwater heaters for each train, three main feedwater pumps (plus three feedwater booster pumps), and two high-pressure feedwater heating trains with two feedwater heaters for each train. For the BWR, the system will include four condensate pumps (one spare) with a full-flow condensate demineralizer system, three low-pressure feedwater heating trains with four feedwater heaters for each train, three feedwater pumps, and two feedwater heater drain tanks and pumps. The system will also incorporate recirculation lines designed to permit system operation when the demand for flow is low, such as during startup and shutdown. Section 4.2.1.8 of Chapter 2 states, in part, that the feedwater and condensate pumps will be designed so that loss of a single feedwater pump (BWR), booster/main feedwater pump assembly (PWR), heater drain pump (BWR), or condensate pump in a multiple pump system will not result in a trip of the turbine-generator or a reactor trip. The staff finds that the design requirements will ensure the availability of adequate feedwater for off-normal transients, thereby reducing challenges to safety-related systems.

Section 4.2.2.4 of Chapter 2 states that double-valve feedwater isolation is required and will be provided by the feedwater control valve and a separate feedwater isolation valve in the main feedwater line to each steam generator. The isolation valve will be located outside the containment and will also serve as a containment isolation valve, but will not be required to close automatically on a containment isolation signal. Both valves will be designed to fail closed on loss of actuating fluid. The design closure time will be justified by safety analysis. These features are intended to prevent excessive reactor coolant system cooldowns and/or containment overpressurizations as a result of the addition of excessive feedwater to the steam generators following a steam line or feedwater line break. These valves will also provide appropriate isolation for the non-safety-related part of the main feedwater system in order to ensure the decay heat removal function of the safety-related auxiliary feedwater system. In addition, a check valve will be provided at each steam generator to prevent reverse flow under accident conditions (such as a feedwater line break) and, thus, prevent the blowdown of more than one steam generator. The staff finds that the feedwater isolation features will ensure postaccident decay heat removal functions in accordance with the requirements of GDC 44, "Cooling Water."

4.3 System Features

Section 4.3 of Chapter 2 of the Evolutionary Requirements Document defines the requirements for feedwater and condensate system components.

Demineralizer/Condensate Polisher

Section 4.3.10.1.1 of Chapter 2 requires the demineralizer/condensate polisher to maintain water quality suitable for long-term power operation, startup, shutdown, and extended outages. Properly designed condensate polishers will be provided to maintain water chemistry within specified limits, assuming a condenser tube leak of 0.001 gpm during continuous operation and 0.1 gpm during an orderly unit shutdown not longer than 8 hours. In addition, the polisher system will provide adequate cleanup function during plant heatup and low-power operation. No regeneration of ion exchange resins will be provided in the system.

In a PWR, a side stream condensate polisher with deep-bed, mixed-resin ion exchangers will be used to maintain feedwater chemistry within specified limits. Section 4.3.10.2.2 of Chapter 2 states, in part, that if the system is sized for less than full condensate flow, it should be capable of handling at least one-third of rated condensate flow. At a site using seawater cooling, a full condensate flow rate system may be required. The sizing of the polisher is intended to protect the steam generators and other secondary-side components from corrosion resulting from poor-quality makeup water. If a full-flow system is not provided, the design and arrangement should include provisions for the possible future installation of full-flow capability. However, the staff is concerned that a side stream condensate polisher may not be adequate for flow control if a full condensate flow rate system is needed. The staff will review this issue on a plant-specific basis.

In a BWR, a deep-bed, mixed-resin, full-flow ion exchange demineralizer will be used. The total condensate flow will be processed through a full-flow filter to remove particulates from the condensate stream before it enters the deep-bed condensate demineralizer. The system will maintain feedwater chemistry within specified limits. The water chemistry in the system will be further controlled by deaerating the condensate during startup and during normal plant operation. In addition, there will be a provision for injecting chemicals into the condenser for biofouling control. EPRI states that the condensate polisher, ion exchange demineralizer, and filter system will be designed to comply with the general requirements in Chapter 1 of the Evolutionary Requirements Document.

The ion exchangers will be provided with internal screens to prevent highly radioactive resin fines from leaving the ion exchangers and being transported to the steam generators (PWR) or reactor pressure vessel (BWR) where they would present a radioactive crud problem. In the event of a failure of one of these internal screens, resin traps (filters) will be located downstream of each ion exchanger to trap any resin fines that leave the ion exchanger. Because the resins in ion exchangers are used to remove radioactive corrosion and fission products from the reactor coolant, ion exchangers are typically large radiation sources that must be shielded to lower the dose rates in adjacent areas. Since the original Evolutionary Requirements Document did not address any design features to minimize personnel exposure during the cleaning of the resin traps, the staff recommended that EPRI address this issue. Section 12.9.3.14 of Chapter 1 has been revised to require that personnel exposure be minimized during cleaning of resin traps by locating these traps outside the ion exchanger enclosure and by providing remote backwash capability for the traps. The staff concludes that this revision addresses the staff's concerns and is, therefore, acceptable.

Capability for Handling Radioactivity

Section 4.3.13 of Chapter 2 states that to reduce the amount of liquid radioactive water that must be processed, BWR condensate, feedwater, and heater drain pump seal leakage will be drained to the condenser hotwell. Any primary-to-secondary PWR leakage will be removed via the steam generator blowdown demineralizers. These demineralizers, as well as the condensate polishers, will be located in areas where temporary shielding can be installed if necessary.

4.4 Component Features

Section 4.4.1.1 of Chapter 2 of the Evolutionary Requirements Document states that the provisions of Chapter 1, requiring that only components that have been proven in comparable service, must be followed. Also, to eliminate overspeed trips on the condensate pumps and the main feed pumps, the design pressure for all components downstream of the pumps will be equal to or higher than the discharge pressure of the respective pumps, assuming no flow (shutoff head developed across pumps). Finally, portions of the feedwater and condensate system that will be under vacuum during low-power and startup conditions must be designed to prevent air inleakage and to maintain acceptable water chemistry.

Condenser

Section 4.4.3 of Chapter 2 requires that the condenser be designed in accordance with Heat Exchanger Institute standards. The condenser will have two or more parallel circulating water flow paths. Tubing must be of commercially available lengths. The design must not preclude shop prefabrication.

In addition, the following requirements must be met:

- The condenser tube material will be Type 304L stainless steel for fresh water with chloride levels below 200 parts per million (ppm). For higher chloride levels of up to 500 ppm, Type 316L stainless steel tubing will be used. A higher grade of stainless steel (such as 904L or AL-6X) must be used if chloride levels are between 500 and 800 ppm. For brackish or salt water containing high concentrations of dissolved solids (1000 ppm) or chlorides (more than 800 ppm) or water contaminated by sewage discharges, titanium tubing will be used.

- Stainless steel tubing material must not be thinner than 22 British Wire Gauge (BWG). Titanium tubing material must not be thinner than 23 BWG. Impingement protection will be provided. Tube support plates will be designed to minimize tube vibrations.

- Provisions for chemical injection into the condensate for biofouling control must be included in accordance with site-specific requirements and applicable regulations.

- Means will be provided to protect the tubes from pitting when the condenser is shut down.

- Tube sheets will be specified as follows:

  - For Type 304L stainless steel tubes, Type 304L stainless-clad carbon steel tube sheets must be used.

  - For Type 316L stainless steel tubes, Type 316L stainless-clad carbon steel tube sheets must be used.

  - For higher grade stainless steel tubes, stainless-clad carbon steel tube sheets must be used.

  - For titanium tubing, titanium-clad carbon steel tube sheets must be used.

- Double tube sheets or welded tube-to-tube-sheet joints will be pro-vided.

- Formation of corrosion products and loss of condenser materials will be minimized by eliminating steel surfaces that could erode and/or using materials other than carbon steel.

- Leak-detection trays will be included at all tube-to-tube-sheet interfaces. Provisions for early leak detection will be provided at tube sheet trays and in each hotwell section. The hotwell will be divided into sections so that leaks can be detected and located.

The staff concludes that these requirements are acceptable because corrosion-resistant materials are to be used in the construction of the condenser. Also, leak-detection trays are required to provide for early leak detection.

Feedwater Heater and Deaerator

Section 4.4.4.1 of Chapter 2 specifies that feedwater heaters tubes be Type 304L stainless steel with carbon steel tube sheets. Tube-to-tube-sheet joints must be welded.

The staff concludes that these requirements are acceptable because Type 304L stainless steel tubes have shown good resistance to the type of physical and chemical attack common in the power plant feedwater system environment.

Regulating Valves

Section 4.4.8.1 of Chapter 2 requires that appropriate stainless steel materials be specified for all valve bodies and internal components, including heater drain valves, for regulating applications in the feedwater and condensate systems. Design features to facilitate inspection, maintenance, and replacement, as required, of regulating valve internal components or valve seats will be provided.

The staff concludes that these requirements are acceptable because stainless steel will provide increased resistance to cavitation and erosion damage.

4.5 Instrumentation and Controls

Section 4.5 of Chapter 2 of the Evolutionary Requirements Document requires instrumentation and control equipment for the feedwater and condensate system, including

- heat balance instrumentation
- reactor and turbine trips
- level controls
- turbine water induction prevention controls
- condenser hotwell level control
- feedwater string isolation valves
- deaerator storage tank level control (PWR)
- feedwater heater drain controls
- pump trips

4.6 Maintenance

Section 4.6 of Chapter 2 refers to the general maintenance requirements in Chapter 1 of the Evolutionary Requirements Document. EPRI states that the requirements in Section 4.6 of Chapter 2 are intended to ensure that maintenance of all feedwater and condensate system components can be accomplished quickly and safely Section 4.6 of Chapter 2 requires that the specific provisions for ease of access, adequacy of work space, and laydown areas be addressed during the design phase.

4.7 Conclusion

The staff concludes that the EPRI requirements for the design of the feedwater and condensate system do not conflict with SRP Section 10.4.6, "Condensate Cleanup System," and SRP Section 10.4.7, "Condensate and Feedwater System," and are acceptable.

5 CHEMICAL ADDITION SYSTEM

5.1 System Definition

The chemical addition system will be designed to add liquid (for PWR) or gaseous (for BWR) chemicals as necessary to maintain condensate, feedwater, and the off-gas (for BWR) system chemistry within the required limits.

5.2 Performance Requirements

Section 5.2.1 of Chapter 2 of the Evolutionary Requirements Document requires that the chemical addition systems for PWRs maintain water quality for long-term operation during all plant conditions. The system will have sufficient capacity to continuously inject chemicals for 24 hours to limit the need to replenish the chemicals. Specific feedwater chemistry requirements are given in Chapter 3.

Section 5.2.2 of Chapter 2 requires that the gas addition system for BWRs be capable of maintaining the required gas concentrations at all power levels above 30 percent of full power. Hydrogen addition is part of the industry's BWR Hydrogen Water Chemistry Program, discussed in further detail in Chapter 1 of this report. The system will be capable of providing the prescribed gas concentrations 90 percent of operating time.

5.3 System Features

PWR

Section 5.3.1 of Chapter 2 specifies, for PWRs, that separate and identical equipment and tubing for adding and injecting hydrazine and ammonia or morpholine will be provided in the chemical addition system. The system will consist of the chemical addition tanks, pumps, piping, instrumentation, and addition points on the condensate and feedwater system. Chemicals will be injected into the condensate line downstream of the condensate polisher and into the suction line of each feedwater booster pump. The performance requirements specify that the system will be capable of injecting suitable amounts of hydrazine and ammonia or morpholine during plant operation and during plant layups.

BWR

Section 5.3.2 of Chapter 2 specifies, for BWRs, that the chemical addition system will consist of gas generation and/or storage facilities, piping, flow metering, instrumentation, and addition points on the feedwater and off-gas systems. Separate gas injection tubing will be provided for (1) injecting oxygen to the condensate, (2) injecting hydrogen into the feedwater, and (3) adding oxygen to the off-gas system.

5.4 Component Features

Sections 5.4.1 and 5.4.2 of Chapter 2 require that the chemical addition pumps in PWRs be fabricated from Type 316 stainless steel and the chemical addition tanks be fabricated from Type 304 stainless steel. Section 5.4.3 requires that the pipe and tubing for the gas addition systems in BWRs be Type 316 stainless steel.

The staff concludes that these requirements are acceptable because the specified materials are compatible with the intended service.

5.5 Instrumentation and Controls

For PWRs, Section 5.5 of Chapter 2 requires automatic control of hydrazine and ammonia addition pumps and level switches with low-level alarms and pump trip controls on chemical addition tanks.

For BWRs, Section 5.5 of Chapter 2 requires automatic control of condensate oxygen addition flow, feedwater hydrogen injection flow, and off-gas oxygen addition flow.

5.6 Maintenance

Section 5.6 of Chapter 2 refers to the general requirements in Section 8 of Chapter 1 of the Evolutionary Requirements Document. Section 5.6 of Chapter 2 requires that chemical addition skids be designed for ease of maintenance and quick replacement of individual components.

5.7 Conclusion

The staff concludes that the EPRI requirements for the design of the chemical addition system do not conflict with SRP Section 5.4.2.1, Branch Technical Position MTEB 5-3, "Monitoring of Secondary Side Water Chemistry in PWR Steam Generators," and with other regulatory requirements and are, therefore, acceptable.

6 CONDENSATE MAKEUP PURIFICATION SYSTEM

6.1 System Definition

The condensate makeup purification system will be designed to treat the raw makeup water and to store the treated water for filling, flushing, and providing makeup water for the feedwater and condensate system. In addition, the system will provide purified water to the primary water storage tank for the PWR plant. The complete system will consist of a demineralizer for removing ionic impurities, a vacuum degasifer for removing dissolved oxygen, a demineralizer water storage tank for sampling, and a condensate storage tank. In same cases, additional equipment may be needed to filter, clarify, and soften the water depending on the quality of the makeup water.

Interfaces

Section 6.1.3 of Chapter 2 of the Evolutionary Requirements Document describes the system interfaces with the raw water makeup system (Chapter 9), the feedwater and condensate system (Section 4 of this chapter), the PWR chemical and volume control (CVC) system (Chapter 3), the process sampling system (Chapter 3), and the fuel pool (Chapter 7). The staff concludes that the cited chapters address the system interfaces.

6.2 Performance Requirements

The condensate makeup purification system will be designed with two 100-percent capacity trains to treat the raw makeup water and to store the treated water for filling, flushing, and providing makeup water for the feedwater and condensate system. In addition, the system will provide purified water to the primary makeup system and the fuel pool in the PWR. Section 6.2 of Chapter 2 requires that the condensate makeup purification system provide condensate makeup water of a quality and quantity suitable for long-term plant operation and for all plant conditions, including power operation, startup, shutdowns, extended outages, and off-chemistry conditions. PWR system capacity will be based on the maximum steam generator blowdown rate and miscellaneous condensate requirements. BWR system capacity will be based on auxiliary steam makeup requirements during plant startup and miscellaneous condensate requirements.

6.3 System Features

Section 6.3 of Chapter 2 specifies condensate makeup purification system features that are required for a typical site with good water quality. Plant designers are required to review raw water quality for each specific site and provide adequate equipment, as required, for pretreatment. Condensate storage and demineralized water storage tanks will be designed to maintain water purity and exclude oxygen. Section 6.3.2 of Chapter 2 requires that the demineralizer system be designed with two 100-percent capacity trains and that it include the following features:

- strainers in backwash lines to eliminate resin carryover during resin backwash

- use of inert resin in mixed-bed vessels

- full-flow recirculation
- resin regeneration
- sight glasses for viewing resin levels in mixed-bed vessels
- resin traps downstream of each demineralizer vessel

6.4 Component Features

Section 6.4 of Chapter 2 specifies specific requirements for components of the condensate makeup purification system, including the demineralizer, vacuum degasifier, demineralized water storage tanks, and condensate storage tanks.

Demineralizer

The demineralizer will include cation, anion, and mixed-bed units. A decarbonator may also be provided depending on the alkalinity of the makeup water. Depending on site-specific raw water quality, the designer may specify a different demineralizer arrangement based on an evaluation of site-specific conditions. This will be evaluated during the staff's review of a COL application.

Section 6.4.1.4 of Chapter 2 requires that demineralizer components be fabricated from the following materials:

- Demineralizer vessels must be constructed of lined carbon steel.
- Demineralizer skid piping must be constructed of polypropylene-lined carbon steel.
- Dilute acid piping must be constructed of Alloy 20.
- The demineralizer waste tank must include a liner that can withstand the corrosive effects of the regenerated waste over the complete range of expected pH values and chemical concentrations. This tank will include provisions for chemical neutralization.
- Demineralizer waste piping may be constructed of Alloy 20 or other corrosion-resistant material such as polyethylene and polypropylene- lined steel. This piping will be routed above grade so that piping leaks can be detected.

The staff concludes that these requirements are acceptable because the materials specified are standard for demineralizer systems.

Vacuum Degasifier

The vacuum degasifier will be of the packed spray tower type design with makeup water injected at the top of the bed through a distribution system. Two vacuum pumps will be provided to maintain system vacuum.

Section 6.4.2.2 of Chapter 2 requires that the degasifier vessel be constructed of rubber-lined carbon steel. All piping valves and fittings should be of Type 304 stainless steel.

The staff concludes that these requirements are acceptable because the materials specified are the standard materials of construction for the vacuum degasifier.

Demineralizer Water Storage Tank

A demineralizer water storage tank (DWST) will be provided to sample the quality of water before its release to the plant. The capacity of the tank will be based on the design flow rate of the demineralizer and the makeup requirements of the condensate storage tank.

Section 6.4.3.2 of Chapter 2 requires that the DWST be constructed of stainless steel. A stainless steel floating cover on the tank is recommended to minimize air ingress.

The staff concludes that these requirements are acceptable because the materials specified are the standard materials of construction for the DWST. Also, experience has shown that floating covers are an effective method for minimizing air ingress, which can result in aeration of the demineralized water.

Condensate Storage Tank

The minimum capacity of the condensate storage tanks will be based on the maximum use of condensate during startup (e.g., for the PWR, maximum steam generator blowdown level startup duration) plus a 100-percent margin. For BWRs the requirements of the reactor core isolation cooling system and high-pressure injection system will also be considered. A minimum of two pumps will be provided for recycling condensate back to the degasifier or forwarding it to the locations where it will be used in the plant.

Section 6.4.4.2 of Chapter 2 requires that the condensate storage tanks be constructed of stainless steel. Stainless steel floating covers on the tanks are recommended to minimize air ingress.

The staff concludes that these requirements are acceptable because the materials specified are the standard materials of construction for the condensate storage tank. Also, experience has shown that floating covers are an effective method of minimizing air ingress, which can result in aeration of the demineralized water.

6.5 Instrumentation and Controls

Section 6.5 of Chapter 2 requires that the condensate makeup purification system be controlled and monitored from local control panels. Provisions will be made for manual control as backup to the automatic of semiautomatic control. Table 2.6-1 of Chapter 2 tabulates the parameters that should be maintained throughout the demineralizer system. Section 6.5.6 of Chapter 2 requires that provisions be made for appropriate trips and/or isolations to protect against chemical intrusions (i.e., when limits of silica, sodium, or conductivity in demineralizer effluent are exceeded).

6.6 Maintenance

Section 6.6 of Chapter 2 requires that the condensate makeup sampling system be located near the processing equipment within an environmental enclosure to protect operators and equipment from adverse effects of temperature, humidity, chemical or steam leaks, and local noise.

6.7 Conclusion

The staff concludes that the design requirements for the condensate makeup purification system do not conflict with SRP Section 9.2.3, "Demineralized Water Makeup System," and are acceptable.

7 AUXILIARY STEAM SYSTEM

7.1 System Definition

The auxiliary steam system will be designed to supply low-pressure non-radioactive steam to various plant components when the main steam system is not available and to be the normal source of steam for the radioactive waste evaporators.

7.2 System Interfaces

The auxiliary steam system will interface with the following systems:

- main steam system (Section 3 of this chapter)
- deaerator (PWR) and steam jet air ejectors in the feedwater and condensate system (Section 4 of this chapter)
- turbine gland sealing system (Chapter 13)
- boron recycle system (PWR) (Chapter 12)
- PWR chemical and volume control system (Chapter 3)
- liquid radioactive waste system evaporator, if used (Chapter 12)
- space and hot water heating system (Chapter 9)
- process sampling system (Chapter 3)
- BWR reactor core isolation cooling turbine test system (Chapter 5)

7.3 Performance Requirements

Section 7.3.1 of Chapter 2 of the Evolutionary Requirements Document states that the auxiliary steam system will have no safety-related function and will provide steam for the following:

- deaerator pegging (PWR)
- steam jet air ejectors in the feedwater and condensate system
- turbine gland sealing
- boron recycle evaporator and batch tank in PWR chemical and volume control system
- liquid radioactive waste evaporator/concentrator
- reactor core isolation cooling turbine test (BWR)
- space and hot water heating system

The system will provide the plant with the operational flexibility necessary to supply the required steam loads during all modes of plant operation.

Section 7.3.3 of Chapter 2 states that the system will be designed to maintain steam quality consistent with the requirements of the feedwater and condensate system.

7.4 System Features

Section 7.4 of Chapter 2 requires that the auxiliary steam system be supplied with steam from a package steam boiler for plant startup and from the steam system for normal operation. Each source of steam will include a separate motor-operated gate valve to isolate the steam from the in-plant auxiliary steam header. Condensate formed in the steam components will be collected in a condensate collection tank and routed to the auxiliary steam boiler's deaerator. Since the original Evolutionary Requirements Document did not address the prevention of contamination of the auxiliary steam system by radioactive liquid, the staff recommended that EPRI address this issue. Section 7.4.3 of Chapter 2 was revised to require that the auxiliary steam system be designed to prevent contamination by either radioactive steam or liquid. The staff concludes that this revision will serve to reduce personnel exposure and is, therefore, acceptable.

7.5 Component Features

Section 7.5 of Chapter 2 states that only components with proven service will be used in the auxiliary steam system. Section 7.5.5 of Chapter 2 states that the auxiliary steam boiler system will consist of two condensate collecting pumps, two boiler makeup pumps, and two boiler feed pumps. Each pump will be 100-percent flow and will be provided with a constant recirculation line to meet minimum flow requirements.

7.6 Maintenance

Section 7.6 of Chapter 2 refers to the general maintenance requirements in Section 8 of Chapter 1 of the Evolutionary Requirements Document.

7.7 Conclusion

Since the auxiliary steam system will have no safety-related function and the NRC has no regulatory requirements for the system, the staff concludes that the design requirements for the system generally reflect good engineering practice and are acceptable.

8 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 2 of the Evolutionary Requirements Document for the design of power generation systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine that the plant-specific design, operation, and arrangement of the power generation systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the Standard Review Plan (SRP) (NUREG-0800), or provide justification or alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 2 of the Evolutionary Requirements Document specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose power generation systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 2 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume I of this report.

CHAPTER 3, "REACTOR COOLANT SYSTEM AND REACTOR NON-SAFETY AUXILIARY SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 3, "Reactor Coolant System and Reactor Non-Safety Auxiliary Systems," of Evolutionary Requirements Document through Revision 3. Chapter 3 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering Nuclear Power; Bechtel Power Corporation; Duke Power Company, General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Sargent and Lundy; Westinghouse Electric Corporation; and EPRI.

On June 18, 1987, EPRI submitted Chapter 3 of the Evolutionary Requirements Document for staff review. By letters dated November 18 and December 11, 1987, the NRC staff requested that EPRI supply additional information. EPRI provided the information in its responses dated January 25 and March 28, 1988. Topic papers in Appendix B of the original version of this chapter were relocated to Appendix B to Chapter 1.

On May 13, 1988, the staff issued its DSER for Chapter 3 of the Evolutionary Requirements Document. On July 12, 1990, the staff and EPRI met with the Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on Improved Light Water Reactors to discuss Chapter 3, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 3, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 3 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 3

Chapter 3 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the reactor coolant system and reactor non-safety auxiliary systems.

The key topics addressed in the Chapter 3 review include EPRI-proposed design requirements for the

- PWR reactor coolant system
- steam generator system (PWR)
- BWR reactor coolant system
- chemical and volume control system (PWR auxiliary)
- process sampling systems (BWRs and PWRs)

• reactor water cleanup system (BWR auxiliary)

1.3 Policy Issues

During its review of Chapter 3 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 3 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) bolting degradation or failure (Generic Safety Issue (GSI)29) (2.2)
(2) low-temperature overpressure protection (3.3)
(3) pressurizer relief tank system (3.3)
(4) reactor coolant pressure boundary leakage detection systems (3.3)
(5) automatic isolation of component cooling water to reactor coolant pumps (3.4)
(6) cooling of reactor coolant pump seal during station blackout (GSI-23) (3.4)
(7) BWR main steam isolation valve leakage control (GSI-C-8) (5.3)

Confirmatory Issues

(1) protection of noncritical components inside containment (2.2)
(2) overfrequency transient during loss of electrical load (3.2)
(3) non-safety-related power supply design (3.2)
(4) power for pressurizer heaters (Three Mile Island Action Plan Item II.E.3.1) (3.4)
(5) reactor coolant temperature instrumentation for cold leg (3.5)
(6) actuation of emergency feedwater system (4.2)
(7) steam piping supports (4.3)
(8) corrosion-resistant bolting (4.4)
(9) contaminant limits for abrasives (4.4)
(10) eddy current inspection procedures (GSI-67.7.0) (4.4)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All issues identified in the DSER for Chapter 3 of the Evolutionary Requirements Document have been resolved.

1.5 Vendor- or Utility-Specific Items

These vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs.

The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.3.V-1 power supplies for power-operated relief valves (3.3)
E.3.V-2 pressurizer heater power source control design (3.4)
E.3.V-3 chemical and volume control system design (6.2)

2 REQUIREMENTS COMMON TO BWRs AND PWRs

2.1 Definition

Section 2 of Chapter 3 of the Evolutionary Requirements Document contains utility requirements for the reactor coolant system and non-safety-related auxiliary systems that are common to BWRs and PWRs. These requirements pertain to boundaries and interfaces with other plant systems, general system features, instrumentation and controls, and maintenance. The staff concludes that the requirements of Section 2.2 of Chapter 3 do not conflict with NRC requirements and are, therefore, acceptable.

2.2 Common Requirements

Class 1E Power Supplies

Section 2.2.1.1 of Chapter 3 of the Evolutionary Requirements Document requires that critical components located inside the containment and required to function after a loss-of-coolant accident (LOCA) be protected and located so that they will not be damaged by hydrogen burn or flooded as a result of the LOCA. This requirement conforms with SRP Section 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated With the Postulated Rupture of Piping." However, in a letter dated November 13, 1987, the staff informed EPRI that noncritical components should also be protected to the extent that their failure will not degrade Class 1E power supplies. In the DSER for Chapter 3, the staff stated that EPRI, in a letter dated January 3, 1988, had committed to add a requirement stipulating that noncritical electrical components located inside the containment will be protected so that their failure will not cause degradation or failure of Class 1E power supplies. Also, adequate electrical isolation, physical separation, and/or circuit protection will be provided to ensure that degradation or failure of Class 1E power supplies will not result. In the DSER for Chapter 3, the staff concluded that these additional provisions were acceptable and identified this as a confirmatory issue.

In a letter dated February 3, 1992, EPRI revised Section 2.2.1.4 of Chapter 3 to require that electrical components inside the containment be protected so that their failure will not prevent Class 1E power supplies from fulfilling their intended safety function. The staff concludes that the revised requirement addresses its concern. Therefore, this DSER confirmatory issue is closed.

Environmental Qualification

Section 2.2.1.2 of Chapter 3 states that the plant designer will specify the environmental qualification requirements for critical components that are located inside the containment and are required to function after a LOCA occurs. The requirements to be specified include preparation and control of documentation packages demonstrating compliance with NRC requirements. The staff's detailed evaluation of EPRI's requirements concerning environmental qualification is provided in Section 4.8.2 of Chapter 1 of this report.

Structural Requirements

Section 2.2.2 of Chapter 3 of the Evolutionary Requirements Document states that the pressure-integrity design of components and the design of component supports will meet the general requirements in Section 4 of Chapter 1 of the Evolutionary Requirements Document. The staff's evaluation of these general requirements is provided in Section 4 of Chapter 1 of this report.

Provisions for Decontamination

Section 2.2.5 of Chapter 3 states that the design of the reactor coolant system (RCS) will include provisions to facilitate chemical decontamination to reduce shutdown radiation levels in piping and components. These provisions will include use of drain and flush connections to ensure removal of decontamination fluids, in-line components to minimize trapping of decontamination fluids, appropriate curvatures and connections to allow a probe (i.e., a hydrolaser) to pass inside the piping. The RCS will be designed to permit the use of mechanical decontamination devices. EPRI requires that plant designers ensure that materials to be exposed to the decontamination fluids will either be compatible with the reagents or chemicals to be used or be designed to be replaceable. To facilitate the installation and operation of the equipment needed to perform a full or partial decontamination of the RCS, staging areas should be provided in the containment. The staff initially was not aware that the Evolutionary Requirements Document addresses the availability of adequate staging areas in the containment to perform either a full or partial decontamination of the RCS, and therefore, did not evaluate the requirements for these design features in its DSER for Chapter 3. However, Section 2.2.5.1 of Chapter 3 and Sections 6.1.1 and 6.1.3 of Chapter 9 of the Evolutionary Requirements Document state that the RCS design will include provisions to facilitate chemical decontamination and that the RCS will be designed to interface with major decontamination equipment. The staff concludes that these requirements are acceptable.

Insulation

Section 2.2.7 of Chapter 3 requires that designated piping and components for the ALWR be provided with insulation that can be removed quickly and that is designed for reuse. This insulation will be lightweight to facilitate quick removal and installation in those areas where external access is required for inservice inspection. Adequate laydown storage space will be provided for insulation that has been removed. These features will reduce the time required to perform inservice inspections of piping and components in high dose rate areas and therefore will result in dose savings.

Instrumentation

Section 2.2.10 of Chapter 3 provides general requirements that affect the locations of instrumentation. Sensors must be located in low-radiation areas so as to minimize personnel radiation exposure. These general specifications for instrumentation and control (I&C) do not involve any apparent violations of NRC requirements. However, the staff's detailed review of EPRI's I&C design requirements is provided in Chapter 10 of this report.

Use of Robotics

Section 2.2.13 of Chapter 3 requires that the RCS arrangement facilitate the use of robotic technology for inspection and maintenance operations. Nuts on all major openings of the reactor coolant pressure boundary will be designed to facilitate engagement by a remote handling or robotics tool. The use of robotics for inspection and maintenance operations in radiation areas will reduce personnel doses.

Snubbers

Section 2.4.4 of Chapter 3 of the Evolutionary Requirements Document specified that, if hydraulic snubbers are used in an ALWR plant design, the plant designer must establish test requirements that include tests of the snubbers' dynamic characteristics. The EPRI requirements for snubbers have been removed from Chapter 3 and relocated to Section 4.2.3.5 of Chapter 6. Also, EPRI's requirements to address Generic Safety Issue (GSI) 113,"Qualification Testing Requirements for Large Hydraulic Snubbers," are presented in Section 3.3.4 of Appendix B to Chapter 1. The staff's review of these requirements is provided in Section 3.2.43 of Appendix B to Chapter 1 and Section 4.2.3 of Chapter 6 of this report.

Bolting

In the DSER for Chapter 3, the staff stated that in a letter dated July 9, 1987, EPRI had notified the staff that its topic paper on GSI-29, "Bolting Degradation or Failure in Nuclear Power Plants," will be addressed in a future supplement to the Evolutionary Requirements Document. This was identified as an open issue in the DSER. EPRI has revised Appendix B to Chapter 1 of the Evolutionary Requirements Document and specifies requirements to address the staff's resolution of GSI-29. The staff's evaluation of this issue is provided in Section 3.2.22 of Appendix B to Chapter 1 of this report. Therefore, this DSER open issue is closed.

2.3 Conclusion

The staff has not identified any requirements in Section 2 of Chapter 3 of the Evolutionary Requirements Document that conflict with regulatory requirements, therefore, concludes that they are acceptable.

3 PWR REACTOR COOLANT SYSTEM

3.1 System Definition

The PWR reactor coolant system (RCS) will transport hot primary coolant from the reactor vessel to the steam generators and cooled primary coolant from the steam generators to the reactor vessel. During both normal and upset conditions, the pressurizer will maintain pressure in the RCS within specified limits for all anticipated reactor coolant transients without dependence on pressure-relief devices. The RCS will also be designed to provide overpressure protection, support natural circulation sufficient to remove decay heat from the reactor, and, following severe accidents, provide for high point venting of hydrogen and other noncondensible gases.

3.2 Performance

Operational Capability

Section 3.2.1.3 of Chapter 3 of the original Evolutionary Requirements Document required that the RCS and its instrumentation be designed to withstand the overfrequency transient caused by a total loss of plant electrical load. In a letter dated November 13, 1987, the staff asked EPRI why the RCS and its instrumentation should not also be required to withstand the voltage transients that accompany a total loss of electrical load. In the DSER for Chapter 3, the staff stated that in its letter dated January 25, 1988, EPRI had responded that the RCS and its instrumentation are to be designed to withstand the effects of a separation of the plant from its electrical grid, including all electrical effects of the accompanying electrical transient. Accordingly, EPRI committed to modify the requirement to specifically require this equipment to withstand the voltage transients that accompany a total loss of electrical load. The staff concluded that this was acceptable and identified this as a confirmatory issue in the DSER.

EPRI has revised Section 3.2.1.3 of Chapter 3 by requiring that the design of the RCS specifically provide for the effects on the electrical systems (e.g., overfrequency or overvoltage) of load rejection of various amounts up to and including total load rejection. Because the revised requirement identifies both overfrequency and overvoltage transients as effects accompanying loss of electrical load, the staff concludes that EPRI has met its commitment. Therefore, this DSER confirmatory issue is closed.

Section 3.2.1.4.2 of Chapter 3 of the original Evolutionary Requirements Document stated that the plant designer will perform analyses to ensure that an upset in any non-safety-related electrical power supply will not result in conditions that result in reactor scram. In the DSER for Chapter 3, the staff stated that in its letter dated January 25, 1988, responding to a staff question, EPRI had stated that this section was not intended to require that the reactor remain at full power with loss of offsite power. Therefore, the diesels are not of a size to maintain full electrical loads including reactor coolant pumps and main feedwater pumps. To clarify the intent, EPRI committed to revise this section to require that the plant designer implement the design of non-safety-related electrical power supplies so that upsets in these supplies that result in reactor scram will be minimized. This was identified as a confirmatory issue in the DSER.

The staff has verified that EPRI has revised Section 3.2.1 of Chapter 3 by deleting the original Section 3.2.1.4.2, thereby removing the requirement that the reactor remain at full power after loss of offsite power. Therefore, this DSER confirmatory issue is closed.

Section 3.2.1.6 of Chapter 3 of the original Requirements Document specifies that the steam generator, pressurizer, and water level control system of the steam generator will be designed so that a trip of an operating condensate pump or feed pump will not result in a turbine trip or reactor trip. This requirement, intended to improve plant availability, has been removed from Chapter 3 and relocated to Section 3.5.5 of Chapter 1 and Section 4.2.1.8 of Chapter 2 and has been evaluated as part of the staff's review of those chapters.

3.3 System Features

Low-Temperature Overpressure Protection

Section 3.3.2.1 of Chapter 3 of the original Evolutionary Requirements Document specified that the size and spray capacity of the pressurizer will be sufficiently large that automatically actuated power-operated relief valves (PORVs) will not be required to mitigate overpressure transients. In a letter dated November 13, 1987, the staff asked if this meant that PORVs will not be used in the ALWR designs. In a letter dated January 25, 1988, EPRI responded that the intent was not to follow the present practice of using PORVs that are automatically actuated at a pressure somewhat above normal operating pressure to limit the challenges to pressurizer safety valves. However, PORVs may be used to satisfy other requirements such as that pertaining to safety depressurization in Section 5.5 of Chapter 5 and Evolutionary Requirements Document.

The requirements formerly in Section 3.3.2.1 of Chapter 3 regarding the size and spray capacity of the pressurizer and the use of automatically actuated PORVs have been deleted in subsequent revisions of the Evolutionary Requirements Document.

The use of pressurizer PORVs is a design consideration to be determined by the plant designer. If they are used in the safety depressurization and vent system, Section 5.5.4.1.2 of Chapter 5 requires that two valves in series be provided for each train such that vent flow can be terminated, assuming a single failure. The staff will review individual applications for FDA/DC to ensure that the requirements of Item II.G.1 of NUREG-0737 ("Clarification of TMI Action Plan Requirements") regarding assignment of power supplies to these valves is considered.

Section 3.3.2 of Chapter 3 contains general requirements to address the issue of low-temperature overpressure protection (LTOP). EPRI states that the residual heat removal (RHR) pressure relief system will provide LTOP. Section 3.3.2.1 of Chapter 3 requires that the relief capacity for LTOP be sized as required in Section 5.2 of Chapter 5 of the Evolutionary Requirements Document for the RHR system. In addition, Section 3.3.2.3 of Chapter 3 specifies that the nil ductility temperature (RT_{NDT}) of ferritic RCS boundary materials will not exceed 10 °F. In the DSER for Chapter 3, the staff stated that it will make a final judgment on the adequacy of EPRI's LTOP provisions after new NRC requirements have been determined as part of the resolution of this issue. This was identified as an open issue in the DSER. EPRI has relocated its proposed requirements to address the resolution of GSI-94, "Additional Low Temperature Overpressure Protection of Light Water Reactors," from Chapter 3 to Appendix B of Chapter 1. The staff's evaluation of these requirements is provided in Section 3.2.34 of Appendix B to Chapter 1 of this report. Therefore, this DSER open issue is closed.

In the DSER for Chapter 3, the staff noted that Section 3.3.2 of Chapter 3 did not address or provide guidance on the design of the pressurizer relief tank system and identified this as an open issue. In a letter dated May 22, 1991, EPRI responded to the staff's comment by stating that the ALWR will not have a pressurizer relief tank and that pressurizer relief valves will relieve into the in-containment refueling water storage tank. On the basis of this clarification, the staff considers this open issue closed.

Reactor Coolant Water Chemistry

Section 3.3.3 of Chapter 3 specifies reactor water chemistry requirements intended to meet the guidelines in EPRI NP-4762-SR, "Primary Water Chemistry Guidelines," Revision 1. Water quality requirements for pure water from the makeup water storage tank and borated water from the boric acid storage tank are included. The staff concludes that these requirements are consistent with the criteria in SRP Sections 9.2.3, "Demineralized Water Makeup System," and 9.3.4, "Chemical and Volume Control System (PWR) (Including Boron Recovery System)," and are, therefore, acceptable.

Leak Detection Capability

Sections 3.1.3.9, 3.1.3.10, 3.3.2.2, 3.3.4, and 3.3.4.2 of Chapter 3 of the original Evolutionary Requirements Document briefly mentioned leakage from various components. However, EPRI did not provide guidance for the design of reactor coolant pressure boundary (RCPB) leakage detection systems. These systems are needed to provide information to the operators so that corrective action can be taken. This was identified as an open issue in the DSER for Chapter 3.

EPRI has revised Section 3.3.4.1 of Chapter 3 to describe RCPB leakage detection capability. Section 3.3.4 of Chapter 3 states that the reactor coolant system design will accommodate the detection of leakage from the reactor coolant system so that pressure boundary leakage can be detected with adequate confidence to support the leak-before-break methodology. Requirements for the overall reactor coolant leak detection system are specified in Section 7.14 of Chapter 10 of the Evolutionary Requirements Document. Section 7.14.2 of Chapter 10 states that reactor coolant leak detection man-machine interface systems (M-MIS) will monitor the quantities and parameters necessary to determine the magnitude and location of reactor coolant leakage. This monitoring will be automatic, and the data will be stored as a permanent record. Leakage from the reactor coolant system that cannot be located and proved to not be through cracks in the reactor coolant boundary will require shutdown even though the leakage is well within the makeup capability. In its letter dated May 22, 1991, EPRI stated that the plant designer will determine if leakage from such items as reactor coolant pump flanges and seals and pressurizer safety valves should be identified as unidentified leakage in accordance with plant technical specifications.

SRP Section 5.2.5, "Reactor Coolant Pressure Boundary Leakage Detection," requires that the leakage detection system be capable of identifying, separately monitoring, and collecting leakage from both identifiable and unidentifiable sources and that indicators and alarms be provided in the control room for each of the leakage detection systems. General Design Criteria (GDC) 30 of Appendix A to 10 CFR Part 50 requires that means be provided for detecting and, to the extent practical, identifying the source of reactor coolant leakage. In Appendix B to Chapter 1 of the Evolutionary Requirements Document, EPRI commits to comply with the guidance in SRP Section 5.2.5 and GDC 30. The staff has reviewed the related sections in Chapters 3 and 10 of the Evolutionary Requirements Document and concludes that the design of the RCPB leakage detection systems meets GDC 30 and SRP Section 5.2.5 with respect to the detection, identification, and monitoring of the source of reactor coolant leakage and is acceptable. Therefore, this DSER open issue is closed.

3.4 Component Features

Reactor Coolant Piping and Connections

Section 3.4.1 of Chapter 3 of the Evolutionary Requirements Document requires that, to avoid inservice inspection of longitudinal piping welds, all reactor coolant piping be seamless. In addition, forging instead of casting will be the reference fabrication method for reactor coolant piping. Forged piping requires less inservice inspection; therefore, the use of forged and seamless reactor coolant piping in the EPRI ALWR will result in lower overall personnel doses.

Reactor Coolant Pumps

Section 3.4.2.2.1 of Chapter 3 of the original Evolutionary Requirements Document required that component cooling water (CCW) to the reactor coolant pumps and motors not be isolated on an automatic containment isolation signal. However, operation of the reactor coolant pumps without cooling water will be limited to a few minutes. Plant operators will manually isolate the cooling water flow if it becomes a release path from the containment during a loss-of-coolant accident (LOCA). By not requiring automatic isolation of pump cooling water on a containment isolation signal, component degradation due to inadvertent or test actuation of containment isolation can be avoided and continued long-term pump operation in an actual event can be permitted. Thus, in the DSER for Chapter 3, the staff concluded that there was merit to not requiring that the CCW to the reactor coolant pumps and motors be automatically isolated on the receipt of a containment isolation signal. However, the staff recommended that EPRI extend the requirement to include provisions to ensure that the main control room operator has the necessary information and bases to determine when it is appropriate to isolate the affected line by remote manual means and how fast the line should be isolated. This was identified as an open issue in the DSER.

Section 3.4.2.3.1 of Chapter 3 has been revised to state that CCW to the reactor coolant pumps and motors will not be isolated on an automatic containment isolation signal. However, the main control room operators will be provided with the necessary information (e.g., from radiation monitoring instrumentation in the CCW return lines) and bases to determine when it is necessary to isolate the affected line from the main control room. EPRI states that main control room operators will manually isolate cooling water flow if it becomes a release path from the containment during a LOCA. The staff concludes that the provisions included by EPRI to require the control room operators to have the necessary information and bases to determine when it is necessary to isolate the affected line are acceptable. Therefore, this DSER open issue is closed.

Sections 3.4.2.2, 3.4.2.6, 3.4.2.11, and 6.3.1 of Chapter 3 of the original Evolutionary Requirements Document included utility requirements that resolve GSI-23, "Reactor Coolant Pump Seal Failures," for the ALWR, assuming they could be met in specific plant designs. However, it appeared that some of these requirements may not be practical without the development of adequate pump seals and/or the provisions of independent seal cooling. In the DSER for Chapter 3, the staff stated that, unless otherwise determined at the time this issue is resolved, new plant designs should provide independent seal cooling during station blackout. This was identified as an open issue in the DSER.

The staff's evaluation of EPRI's requirements to address GSI-23 is provided in Section 3.2.20 of Appendix B to Chapter 1 of this report. Therefore, this DSER open issue is closed.

Pressurizer

Sections 3.4.3.4.3 and 3.4.3.4.4 of Chapter 3 in the original Evolutionary Requirements Document defined requirements for the power supply to pressurizer heaters. They specified that the combination of maximum heat loss from the pressurizer and pressurizer heater capacity be such as to maintain the pressurizer at normal operating pressure during hot standby conditions and that this capability be provided by redundant trains of heaters. EPRI also stated that each train is to be capable of being supplied electricity from either offsite power or the Class 1E emergency power source. Although the redundant heaters are not required to be safety grade, Section 3.4.3.4.3 required that adequate provisions, such as those listed in Item II.E.3.1 of NUREG-0737, be provided to protect the emergency power trains from failure of the heaters. In a letter dated November 13, 1987, the staff requested that EPRI clarify whether the redundant heaters will be connected to the Class 1E emergency buses in a manner that will provide redundant power supply capability and whether each redundant heater will have access to only one Class 1E division power supply. In a letter dated January 25, 1988, EPRI committed to clarify the requirement to indicate that each redundant train of pressurizer heaters will be capable of being powered from either offsite power or a different Class 1E emergency power source. In the DSER for Chapter 3, the staff concluded that this was acceptable and identified this as a confirmatory issue.

In subsequent revisions of the Evolutionary Requirements Document, EPRI renumbered Sections 3.4.3.4.3 and 3.4.3.4.4 referred to above as 3.4.3.2.3 and 3.4.3.2.4. Also, Section 3.4.3.2.3 now includes a revised requirement that each redundant group of pressurizer heaters be capable of being powered from either offsite power, the alternate ac power source through different permanent non-safety buses, or different Class 1E emergency power sources (as emergency backup). The revisions clarify that each redundant group of pressurizer heaters will be capable of being powered from a different Class 1E emergency power source. Therefore, this DSER confirmatory issue is closed.

With respect to a question in a letter dated November 13, 1987, regarding manual control of the pressurizer heater power sources, EPRI responded in a letter dated January 25, 1988, that the ALWR pressurizer heater design will satisfy the requirements of NUREG-0737, Item II.E.3.1. However, since the specific design details are not given in the Evolutionary Requirements Document, there may be several acceptable methods for controlling pressurizer heater power sources.

The staff concludes that there is reasonable assurance that a pressurizer heater power source design that meets the requirements of these sections will also satisfy the requirements of NUREG-0737, Item II.E.3.1 However, because not all of the specific positions and clarifications of Item II.E.3.1 have been addressed and because specific design details have not been given in the Evolutionary Requirements Document, final acceptance must await the staff's review of specific ALWR designs.

Section 3.4.3.6.1 of Chapter 3 includes a requirement that channel independence for the pressurizer level instrumentation be provided by physical separation, electrical separation, and separate Class 1E electrical power supplies for each channel. Selection of power sources to the pressurizer level indication that is based on the above criteria will also likely satisfy the requirements for emergency power for pressurizer equipment specified in Item II.G.1 of NUREG-0737. This is acceptable for a design requirements document.

3.5 Instrumentation and Control

Section 3.5.1.2 of Chapter 3 of the original Evolutionary Requirements Document specified the instrumentation associated with the reactor coolant system. In the DSER for Chapter 3, the staff stated that, in a letter dated January 25, 1988, EPRI had committed to add reactor coolant temperature instrumentation for the cold leg to the list of required instrumentation. This was identified as a confirmatory issue in the DSER.

The staff has verified that EPRI's revisions to Section 3.5 of Chapter 3 require that plant designers provide the capability for monitoring reactor coolant temperature in the cold leg. Therefore, this DSER confirmatory issue is closed.

3.6 Maintenance

Section 3.6 of Chapter 3 of the Evolutionary Requirements Document contains requirements that are intended to facilitate maintenance of the RCS, including inservice inspection, in accordance with the general requirements of Section 8 of Chapter 1. Maintenance operations involving RCS components will be included in the maintainability evaluations required by Section 2 of Chapter 6.

3.7 Conclusion

The staff concludes the utility requirements in Section 3 of Chapter 3 of the Evolutionary Requirements Document do not conflict with NRC requirements or guidance. However, the details were insufficient to enable a final determination regarding compliance with Items II.E.3.1 and II.G.1 of NUREG-0737. Therefore, the staff will review an individual application for FDA/DC to ensure compliance with these items.

4 STEAM GENERATOR SYSTEM (PWR)

4.1 System Definition

The boundary of the steam generator system will include the welds between steam generator nozzles and reactor coolant piping, main feed piping, emergency feed piping, and main steam piping.

Section 4.1.2 of Chapter 3 of the Evolutionary Requirements Document specifies that the steam generator system will meet the following functional requirements:

- Produce steam with no more than 0.25-percent moisture carryover using reactor coolant as the heat source.
- Provide the capability for continuous hot blowdown of the secondary side of both recirculating and once-through steam generators. Provide the capability for heat recovery, purification, and reuse of steam generator blowdown for recirculating steam generators. The steam generator blowdown rate will permit reasonable plant heatup capability and will permit a transition from cold layup water chemistry to hot standby water chemistry within an 8-hour period.
- Provide an indication of secondary-side water level. Provide automatic control of water level at any power level from hot no load to full power.
- Provide a leaktight boundary between the reactor coolant and the secondary side of the steam generator.
- Serve as the primary means for removing of decay heat from the reactor coolant during plant shutdown using main or emergency feedwater down to a primary coolant temperature that is at a reasonable value below the saturation temperature corresponding to the actuation pressure of the residual heat removal system.
- Provide for full wet layup (water to upper tubesheet) of the steam generator under deoxygenated, pH-controlled conditions.

Section 4.1.3 of Chapter 3 lists the systems with which the steam generator system will interface.

4.2 Performance Requirements

Section 4.2 of Chapter 3 of the original Evolutionary Requirements Document specifies performance requirements applicable to PWR steam generator systems.

Emergency Feedwater Actuation

Section 4.2.3.4 of Chapter 3 of the original Evolutionary Requirements Document included a requirement that automatic actuation occur only after a low water level has been reached in the steam generator and the maximum allowable time for recovery has expired without an acceptable improvement in the water level. In a letter dated November 13, 1987, the staff stated that satisfaction of a timer was implied, whereas actuation of the auxiliary feedwater system needs to be independent of a timer so that no safety parameters are exceeded. In its response dated January 25, 1988, EPRI stated that there was no intent to provide a timer for initiating the emergency feedwater system. The water volume between the level existing following a reactor trip and the level at which the emergency feedwater system is automatically initiated provides a period during which the startup feedwater system can be used (either automatically or manually) to restore the level, or the plant operator can manually initiate the emergency feedwater system.

EPRI committed to revise Sections 4.2.3.4 and 4.2.8.1 of Chapter 3 for clarity. This was identified as a confirmatory issue in the DSER.

The staff has verified that these revisions have been incorporated into Section 4.2 of the Evolutionary Requirements Document; therefore, this DSER confirmatory issue is closed.

4.3 System Features

Elevation Relative to Reactor Vessel

Section 4.3.2.1 of Chapter 3 of the Evolutionary Requirements Document requires that steam generators in the evolutionary PWR be mounted at an elevation above the reactor vessel elevation to permit draining of the primary side of the steam generator (for tube inspection and/or plugging) without lowering the water level in the reactor vessel below the reactor core. The design of the reactor coolant nozzle dams will facilitate their handling and minimize installation time. In addition, these nozzle dams will be designed so that they can be installed and removed using robotics, thereby minimizing personnel exposure.

Steam Piping Support Design Basis

Section 4.3.2.4 of Chapter 3 of the original Evolutionary Requirements Document required that steam piping supports be designed on the basis of the lines filled with water. In the DSER for Chapter 3, the staff reported that in response to a staff request dated December 11, 1987, EPRI had stated in a letter dated January 25, 1988, that it did not intend that dynamic loading be considered for the design of the main steamline supports when subjected to water-filled conditions. EPRI committed to clarify its requirement, and this was identified as a confirmatory issue in the DSER.

EPRI has revised Section 4.3.2.4 of Chapter 3 to require that the main steamline supports be designed for water-filled-line loads under static loading conditions that may be encountered in the plant. The staff concludes that this clarification is acceptable; therefore, this DSER confirmatory issue is closed.

4.4 Component Features

Steam Generator Materials

In the DSER for Chapter 3, the staff stated that bolting resistant to corrosion from boric acid should be used for closure bolting on systems that contain borated water during normal operation. In its letter dated

January 25, 1988, EPRI committed to add a section to the Evolutionary Requirements Document requiring that bolting resistant to corrosion from boric acid be used for closure bolting for systems that contain borated water during normal operation. This was identified as a confirmatory issue in the DSER.

EPRI responded by revising Section 3.1.1 of Appendix B to Chapter 1. This section relates to the resolution of GSI-29, " Bolting Degradation or Failure in Nuclear Power Plants," and addresses the issue of boric acid corrosion of bolting. The staff reviewed this section and found it acceptable. Therefore, this DSER confirmatory issue is closed.

Section 4.4.1.1.3 of Chapter 3 requires, in part, that steam generator tube annealing be followed by chromium carbide precipitation on cooling, rotary straightening, and belt polishing. In a letter dated November 13, 1987, the staff stated that advocating belt polishing without limiting contaminant levels was not acceptable. In a letter dated January 25, 1988, EPRI committed to modify the engineering rationale for Section 5.2.8.1 of Chapter 1 to clarify that the contaminant limits in that overall requirement apply to abrasive adhesives, as well as to cutting fluids, tapes, etc. This was identified as a confirmatory issue in the DSER for Chapter 3.

The staff has verified that EPRI has revised Section 5.2.8.1 of Chapter 1 as stated above and concludes that it is acceptable. Therefore, this DSER confirmatory issue is closed.

Section 4.4.1.1.4 of Chapter 3 requires that the concentration of cobalt in the steam generator tubes be limited to less than 0.015 weight percent. The steam generator tubes constitute a large portion of the total surface area of the reactor coolant system. The tubes for the steam generator will be annealed and thermally treated Ni-Cr-Fe Alloy 690, which has improved resistance to most corrosion mechanisms, and is, therefore, acceptable. In addition, it will tend to reduce the amount of activated cobalt in the reactor coolant system and lower overall dose rates.

Access and Inspection Openings

Section 4.4.1.4 of Chapter 3 requires that clear access, including platforms, be provided to facilitate inspection and maintenance of steam generator tubes. Steam generator primary channel head manholes will be a minimum of 21 inches in diameter. Remotely operated stud tensioning and detensioning devices will be provided to minimize the time spent by maintenance personnel in high dose rate areas when removing and installing the covers for these steam generator manholes. These requirements serve to minimize personnel exposure rates and are acceptable.

In Generic Issue (GI) 67.7.0, "Steam Generator Staff Actions - Improved Eddy Current Tests," the staff considered eddy current inspection procedures that will prevent steam generator tube ruptures as part of its effort to resolve Unresolved Safety Issues A-3, A-4, and A-5 concerning steam generator tube integrity. This was identified as a confirmatory issue in the DSER for Chapter 3. On the basis of the staff's recommendations, EPRI has instituted requirements for the eddy current inspection procedures in Sections 4.4.1.4 and 4.6.2 of Chapter 3. Section 4.4.1.4 gives requirements for the access and inspection openings such as manways, handholes, and ports in the primary and secondary sides of the steam generator. Section 4.6.2 provides requirements for access in the steam generator primary channel head. The staff's evaluation of EPRI's requirements to address resolution of these generic issues is provided in Appendix B to Chapter 1 of this report. Therefore, this DSER confirmatory issue is closed.

Minimizing Sludge Accumulation

Section 4.4.1.6 of Chapter 3 specifies provisions for ensuring a high degree of performance of the steam generators by controlling the accumulation of sludge on the secondary-side tube surface. This control will be achieved by special design features, operating procedures, and use of the steam generator blowdown system. The design of steam generators includes features for removing sludge accumulated on the tubesheet. This accumulation will also be controlled by maintaining sufficiently high velocities across the tubesheet during plant operation above 50-percent power to aid in the transport of particulates to the blowdown nozzle. The impurities accumulated in the steam generator will be removed by the blowdown system, which will reduce sludge buildup and decrease the concentration of dissolved, nonvolatile impurities. The staff concludes that the proposed specifications provide for control of impurities and minimization of sludge accumulation. These specifications are consistent with the criteria of SRP Section 10.4.8, "Steam Generator Blowdown System (PWR) and are, therefore, acceptable.

4.5 Instrumentation and Control

Section 4.5 of Chapter 3 of the Evolutionary Requirements Document specifies requirements pertaining to the following for instrumentation required for the steam generator system: water level control, redundancy, postaccident level indication, and flow measurement

4.6 Maintenance

Section 4.6 of Chapter 3 of the Evolutionary Requirements Document specifies requirements for use of a temporary ventilation exhaust system during personnel access to reduce occupational radiation exposure. The space and arrangement inside the steam generator primary channel head are intended to facilitate inspection and repair.

4.7 Conclusion

The staff concludes that the utility requirements in Section 4 of Chapter 3 of the Evolutionary Requirements Document do not conflict with NRC requirements or guidance.

5 BWR REACTOR COOLANT SYSTEM (BWR NUCLEAR BOILER SYSTEM)

5.1 System Definition

The BWR reactor coolant system (RCS) will transport the main steam from the reactor vessel through the outermost main steam isolation valve and feedwater from the feedwater system to the reactor vessel. In addition, it will be designed to perform the following functions:

- provide recirculation, when required, for reactor coolant
- provide isolation of main steamlines in case of a main steamline break
- provide isolation of RCS lines penetrating the containment, as needed
- provide steamline restrictors to limit the escape of steam from the containment or from the reactor vessel
- provide steam and feedwater flow measurement
- provide the reactor head vent and drain system for normal operation and for shutdown
- provide overpressure protection for all events
- provide the capability to depressurize the reactor vessel
- monitor safety/relief valve (SRV) leakage and the open or close position of SRVs, SRV discharge line vacuum breakers and all valves, except manual drain valves, as needed.

The staff concludes that the utility requirements in Section 5.1 of Chapter 3 of the Evolutionary Requirements Document do not conflict with NRC requirements.

5.2 Performance Requirements

Steady-State and Transient Conditions

Section 5.2.1 of Chapter 3 of the Evolutionary Requirements Document requires that the RCS

- operate during design-basis events and transients, as specified in Sections 2 and 3 of Chapter 1
- have load-following capability under the power-flow map conditions of Chapters 1 and 4
- have detailed requirements and limits of operation for all plant operating modes, including normal operating startup, testing, shutdown, natural variables, planned operation events, moderate frequency events (upset), infrequent events (emergency), and limiting faults

Water Chemistry

Section 5.2.2 of Chapter 3 specifies requirements for RCS chemistry compatible with the operating and layup conditions specified in Section 5 of Chapter 1.

5.3 System Features

Arrangement

Section 5.3.1 of Chapter 3 of the Evolutionary Requirements Document specifies requirements to ensure drainage of condensate, minimize pressure drop, and minimize forces on piping bends. Additional requirements provide for adequate working space for maintenance and other measures to reduce personnel radiation exposure.

Materials

Section 5.3.2 of Chapter 3 specifies materials that have proven to be compatible with expected service conditions.

Main Steamlines

Section 5.3.3 of Chapter 3 contains EPRI's requirements for the main steamlines. Section 5.3.3.8 of Chapter 3 requires that the main steamlines be designated as seismic Category I from the reactor vessel out to the seismic restraint and Quality Group A from the reactor vessel up to and including the outboard main steam isolation valves (MSIVs). BWRs are currently required to incorporate a leakage control system (LCS) to ensure the low-leakage characteristics of the MSIVs in the event of a loss-of-coolant accident. Section 5.3.3.9 of Chapter 3 states that a separate MSIV leak detection and control subsystem will not be provided and that drains and vents will be routed to the main condenser for leakage control. The staff identified the proposed elimination of the LCS as an open issue in the DSER for Chapter 3. As discussed by the staff in Section 5.4 of this chapter, Section 2.3.1 of Appendix B to Chapter 1 of this report provides the staff's evaluation of this issue. Therefore, this DSER open issue is closed.

Recirculation Systems

Section 5.3.4 of Chapter 3 requires that the recirculation systems use adjustable-speed internal pumps mounted on the bottom head of the reactor pressure vessel, and states that these pumps will be referred to as "reactor internal pumps (RIPs)". The RIPs must have the capability to meet the load-following performance requirements in Chapter 1 and be designed to permit stable pump operation over the complete operating map specified in Chapter 4 of the Evolutionary Requirements Document.

Feedwater Systems

Section 5.3.5 of Chapter 3 states that the feedwater system inside primary containment consists of two lines between the primary containment and the reactor pressure vessel feedwater manifold piping. The feedwater piping and sparger design will accommodate the range of temperatures and flows that are experienced during plant operation from feedwater, reactor water cleanup

(RWCU), reactor coolant inventory control, and one of the three loops of the decay heat removal ar. 'ow-pressure emergency coolant makeup systems. Additionally, the feeowater piping and valve arrangement will permit the injection of all feedwater and RWCU flow into the reactor through one of the two feedwater lines during low flow conditions. Top-mounted elbow/nozzles will be used to discharge flow from the feedwater spargers into the recirculating reactor coolant. Multiple feedwater spargers will be provided, if necessary, to obtain uniform distribution and to maintain low stresses in the sparger. Design of the feedwater system piping will avoid water hammer as much as possible.

Section 5.3.5.2 of Chapter 3 originally stated that each feedwater line penetrating the primary containment would be equipped with a simple check valve inside the containment and a positive acting check valve, with spring-assisted seating, outside the containment. A thir remotely operable gate valve with high leak tight capability was required for each feedwater line upstream of the isolation valve outside the containment and was not required to meet the requirements of Appendix J to 10 CFR Part 50. The check valves were specified as the isolation valves. The third valve was provided for positive shutoff when the feedwater system is not in service to permit maintenance of the upstream feedwater system components and to facilitate Appendix J leak testing of the check valves.

Testing of the BWR feedwater system isolation valves was not addressed in the DSER as an open issue. However, after reviewing the above arrangement in the feedwater system, the staff concluded that it was not acceptable to exclude the third valve from the leak testing required in Appendix J. The staff concluded that the above valve arrangement was similar to the typical feedwater line valve arrangement described in American Nuclear Society (ANS) Standard 56.2-1976 as satisfying General Design Criteria 55 of Appendix A to 10 CFR Part 50 on another defined basis. Therefore, the valve arrangement is acceptable. However, as described in Note 55-1 of ANS Standard 56.2-1976, all three of the valves in the above valve arrangement are considered containment isolation valves. Consequently, Appendix J leak testing should be required for all three of the valves. EPRI's original proposal, which did not require the third valve to be Appendix J leak tested, was not acceptable. By letter dated April 17, 1992, EPRI revised its position and deleted the sentence which stated that this valve need not meet the requirements of Appendix J. Therefore, the staff concludes that the revised feedwater system isolation design is acceptable.

5.4 Component Features

Main Steam Isolation Valves (MSIVs)

Section 5.4.1 of Chapter 3 of the Evolutionary Requirements Document contains EPRI's requirements for the MSIVs and incorporates the utility requirements proposed in EPRI's optimization subject paper entitled "BWR Main Steamline Valves and Leakage Control," as discussed in Section 2.3.1 of Appendix B to Chapter 1 of the Evolutionary Requirements Document. Section 2.3.1 of Appendix B to Chapter 1 of this report provides the staff's evaluation of this issue.

Section 5.4.1.4 of Chapter 3 requires that the allowable MSIV leaktightness be determined on the basis of the calculated total dose from all leakage sources and be consistent with the exposure guidelines in 10 CFR 100.11. Section 5.4.1.5 requires that the MSIV leakage specified for the final installed test be less than 50 percent of the allowable value.

Safety/Relief Valves

Section 5.4.2.4 of Chapter 3 specifies that the safety/relief valves and their discharge piping will be designed to relieve pressure and to maintain the pressure boundary within the overpressure protection requirements of ASME Code, Section III, including requirements for prototypical testing. These requirements conform with the elements of resolution of GSI-126, "Main Steam Safety Valves," and are acceptable.

Recirculation Pumps

Section 5.4.3 of Chapter 3 specifies requirements for the RIPs to ensure that the performance of the recirculation system is as specified by Section 5.3.4 of Chapter 3.

5.5 Conclusion

The staff concludes that the requirements of Section 5 of Chapter 3 of the Evolutionary Requirements Document do not conflict with regulatory requirements and guidelines and are, therefore, acceptable.

6 CHEMICAL AND VOLUME CONTROL SYSTEM (PWR AUXILIARY)

6.1 System Definition

The main functions of the chemical and volume control system (CVCS) are to maintain the primary coolant inventory and to control its chemistry. Accordingly, Section 6 of Chapter 3 of the Evolutionary Requirements Document specifies that the capacity of the CVCS should be sufficient to maintain the primary coolant inventory, even in the event of small pipe ruptures. The specifications for the volume control tank require that its capacity have enough margin to allow for realignment of the charging pumps. In addition, the CVCS is required to contain sufficient boron for reactivity control. This section includes a requirement that the CVCS be designed so that there will be easy access for inservice inspections and for chemical cleaning. It also specifies the design and operation of resin demineralizers.

6.2 Performance Requirements

Section 6.2.1 of Chapter 3 of the Evolutionary Requirements Document specifically points out that the CVCS will not perform any safety-related functions, such as accident mitigation or safe shutdown, and this characteristic is reflected in these design specifications. However, insufficient details, particularly for the parameters associated with flow and injection pressure, were provided to enable a determination to be made regarding compliance of the system design with the criteria of SRP Section 9.3.4. Therefore, the staff will review individual applications for FDA/DC against the criteria in SRP Section 9.3.4.

6.3 System Features

Section 6.3 of Chapter 3 of the Evolutionary Requirements Document specifies configuration, arrangements, and structural requirements for the CVCS. However, insufficient details, particularly for the parameters associated with flow and injection pressure, were provided to enable a determination to made regarding compliance of the system design with the criteria of SRP Section 9.3.4.

6.4 Component Features

Section 6.4 of Chapter 3 of the Evolutionary Requirements Document specifies requirements to address materials, centrifugal pump seal design, heat exchangers, volume control tank arrangement and sizing, reactor coolant system coolant hydrogen concentration, boric acid tanks, oxygen control, filters, and valves for the CVCS.

6.5 Instrumentation and Control

Section 6.5 of Chapter 3 of the Evolutionary Requirements Document specifies the process instrumentation and controls required for the CVCS. General requirements for instrumentation and controls applicable to CVCS are provided in Chapter 10.

6.6 Maintenance

Section 6.6 of Chapter 3 of the Evolutionary Requirements Document specifies requirements to facilitate maintenance of the CVCS and references the general requirements located in Section 8 of Chapter 1. Maintenance operations involving CVCS components will be included in the maintainability evaluation required by Section 2 of Chapter 6.

6.7 Conclusion

The staff concludes that the utility requirements in Section 6 of Chapter 3 of the Evolutionary Requirements Document do not conflict with NRC requirements. However, the details were insufficient to enable a final determination regarding compliance with the criteria of SRP Section 9.3.4. Therefore, the staff will review an individual application for FDA/DC to ensure that the criteria of SRP Section 9.3.4 have been met.

7 PROCESS SAMPLING SYSTEMS (BWR AND PWR)

7.1 System Definition

Section 7 of Chapter 3 of the Evolutionary Requirements Document covers the process sampling systems for both PWR and BWR plants. The purpose of these systems is to collect representative samples of liquids and gases in the various process systems and deliver them to one or more central sample stations.

Sampling point locations, types of samples, sample frequencies, and process measurements for both normal and postaccident sampling are listed in this section.

7.2 Performance Requirements

Sampling Required

Section 7.2.1 of Chapter 3 of the Evolutionary Requirements Document states that the process sampling system will provide the process measurements needed to satisfy all regulatory requirements and operational needs.

Grab Samples

Section 7.2.4 of Chapter 3 discusses the use of grab samples for verifying or confirming system performance. The requirements in this section pertain to the sampling of reactor coolant and specify that portable measuring equipment will not be used for taking continuous samples, but only for checking installed monitors.

Postaccident Sampling

Section 7.2.8 of Chapter 3 specifies EPRI's requirements for the postaccident sampling system (PASS). Additional information on the PASS is provided in Section 2.3.2 of Appendix B to Chapter 1 of the Evolutionary Requirements Document. The staff's evaluation of all of the requirements for the PASS is provided in Section 2.3.2 of Appendix B to Chapter 1 of this report.

7.3 System Features

Arrangement

Section 7.3.2 of Chapter 3 of the Evolutionary Requirements Document requires that the lengths of lines to sample stations be minimized in order to obtain representative samples (with minimum radioactive decay and plateout). Sample staiion components carrying potentially radioactive fluids will be located behind a shield wall, and area dose rates in sampling stations will be maintained as low as is reasonably achievable to minimize personnel doses.

7.4 Component Features

Section 7.4 of Chapter 3 of the Evolutionary Requirements Document specifies requirements for process sampling systems, materials, sample lines, isolation valves, and sample coolers.

7.5 Instrumentation and Control

Section 7.5 of Chapter 3 contains specific requirements for process sampling systems, including the boron meter and radiation meter (for PWRs), process radiation monitor, on-line monitors for PWR secondary systems, and data management. General instrumentation and control requirements for the process sampling systems are provided in Chapter 10.

7.6 Maintenance

Section 7.6 of Chapter 3 references the general maintenance requirements of Section 8 of Chapter 1. Section 7.6 of Chapter 3 contains specific requirements for maintenance process sampling systems, valves, components, and piping containing radioactive samples. Flanged fittings are required for relief valves and other components, if necessary, to permit removal for maintenance.

7.7 Conclusion

The staff concludes that the utility requirements in Section 7 of Chapter 3 of the Evolutionary Requirements Document satisfy all the criteria specified for process sampling in SRP Section 9.3.2, "Process and Post-Accident Sampling Systems," for both PWR and BWR plants, and, therefore, the utility requirements for normal sampling are acceptable.

8 REACTOR WATER CLEANUP SYSTEM (BWR AUXILIARY)

EPRI's requirements for the boron recycle system have been deleted from Section 8 of Chapter 3 of the Evolutionary Requirements Document and relocated to other sections. Therefore, the requirements for the reactor water cleanup system, formerly provided in Section 9 of Chapter 3, have been moved to Section 8 of Chapter 3 and renumbered.

8.1 System Definition

The function of the reactor water cleanup (RWCU) system is to remove soluble, colloidal, and insoluble impurities from the reactor coolant in BWR plants by passing a portion of the reactor water, corresponding to at least 1 percent of main steam flow, through filter/demineralizers. Before going to the filter/demineralizers, the water will be cooled by passing through regenerative and nonregenerative heat exchangers.

8.2 Performance Requirements

The specifications for the RWCU system in Section 8 of Chapter 3 of the Evolutionary Requirements Document meet and, in some cases, exceed the recommendations of SRP Section 5.4.8, "Reactor Water Cleanup System (BWR)." For example, EPRI requires that 2 percent of the circulating reactor water pass through the RWCU system, which will have two pumps and two filter/demineralizers in parallel. If one of the components fails, the system will still be capable of handling 1 percent of the circulating water. The system will meet the ALARA (as low as reasonably achievable) radiation exposure requirements by the separation of valves and instruments from the heat exchangers carrying radioactive liquids, by the elimination of crud traps, and by the use of shielding pumps, filter/demineralizers, and other equipment that may contribute to radiation dosage for operations and maintenance personnel. The specifications also require that the system be designed with provisions for decontaminating and draining and filling the system.

8.3 System Features

Section 8.3 of Chapter 3 specifies configuration and arrangement requirements for the RWCU system and for transfer of spent resins.

8.4 Component Features

Section 8.4 of Chapter 3 specifies requirements for RWCU system materials, piping and connections, pumps, valves, heat exchangers, and cleanup equipment.

8.5 Instrumentation and Control

Section 8.5 of Chapter 3 states that the RWCU system should be properly instrumented for the measurement of temperature, conductivity, and pressure differential across the demineralizer beds.

8.6 Conclusion

The staff concludes that the utility requirements in Section 8 of Chapter 3 of the Evolutionary Requirements Document are consistent with the criteria of SRP Section 5.4.8, "Reactor Water Cleanup System (BWR)," and are, therefore, acceptable.

9 CONCLUSION

The staff concludes that the EPRI requirements in Chapter 3 of the Evolutionary Requirements Document for the design of the reactor coolant system and reactor non-safety auxiliary systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the plant-specific design, operation, and arrangement of these systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the Standard Review Plan (NUREG-0800), or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 3 specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose reactor coolant system and reactor non-safety auxiliary systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 3 of the Evolutionary Requirements Document contains definitions of acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

CHAPTER 4, "REACTOR SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 4, "Reactor Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 4 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Westinghouse Electric Corporation; and EPRI.

On June 18, 1987, EPRI submitted Chapter 4 of the Evolutionary Requirements Document for staff review. By letters dated November 13 and December 11, 1987, the staff requested that EPRI supply additional information. EPRI provided the information in its responses dated January 25 and March 26, 1988.

On June 10, 1988, the staff issued its DSER for Chapter 4 of the Evolutionary Requirements Document. On July 12, 1990, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 4, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 4, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 4 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 4

Chapter 4 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the reactor systems.

The key topics addressed in the Chapter 4 review include EPRI-proposed design requirements for the reactor pressure vessel, nozzles and safe-ends, reactor internals, in-vessel portions of fluid systems (including reactor internal pumps, emergency core cooling system piping, and spargers), nuclear fuel, control rods, and the control rod drive system (including hydraulic supply and accumulators). Special tools required for reactor system maintenance, inspection, and testing are also covered, except for refueling and refueling-related tools, which are covered in Chapter 7.

1.3 Policy Issues

During its review of Chapter 4 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 4 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) power oscillations in BWRs (2.2)

(2) low-temperature overpressure protection (Generic Safety Issue (GSI-94)) (2.3)

(3) protection of reactor pressure vessel from brittle fracture (thermocouples/materials surveillance program) (3.3)

(4) performance requirements for BWR core and fuel (thermal-hydraulic stability) (4.2)

(5) effect of electric protective assemblies on reactor protection system power supply requirements (5.3)

(6) effect of natural circulation cooldown on reactor pressure vessel (GSI-79) (6.2)

(7) thermal-hydraulic characteristics of PWRs (7.2)

(8) positive moderator coefficient above 50-percent power (7.3)

(9) 60-year service life of control rod drive mechanisms (8.2)

Confirmatory Issues

(1) low-temperature overpressure protection (2.3.1)

(2) percentage of copper in reactor pressure vessel forging (2.3.1)

(3) reactor pressure vessel surveillance program (2.3.1)

(4) fracture toughness specifications (2.3.1)

(5) irradiation dosage limits for the reactor pressure vessel internals (2.3.2)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All issues identified in the DSER for Chapter 4 have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.4.V-1 reactor pressure vessel fatigue design criteria (2.3.2)

E.4.V-2 BWR thermal-hydraulic stability performance during an anticipated transient without scram (4.2)

E.4.V-3 BWR nuclear and thermal-hydraulic design for extended cycle operation (4.2)

E.4.V-4 effect of electric protective assemblies on reactor protection system power supply requirements (5.3)

E.4.V-5 PWR thermal-hydraulic stability and xenon stability characteristics (7.2)

E.4.V-6 PWR fuel design for load-following capability (7.2)

E.4.V-7 60-year service life for control rod drive mechanisms (8.2)

2 REQUIREMENTS COMMON TO BWRs AND PWRs

2.1 Top-Level Requirements

Section 2 of Chapter 4 of the Evolutionary Requirements Document defines the utility requirements for the ALWR that are common to BWR and PWR reactor systems. As a general requirement, this section specifies that the reactor systems are to be designed to perform the following functions:

- generate the thermal power necessary to meet required plant electrical power output while not exceeding specified nuclear, thermal-hydraulic, and mechanical design limitations

- serve as a pressure boundary and a barrier to prevent the release of radioactivity from the reactor core or reactor coolant

- provide a flow path for the forced circulation of coolant to remove heat generated by the reactor core under all operating conditions and to facilitate removal of decay heat by natural or forced circulation from the core after shutdown

- provide for control of core reactivity

With respect to instrumentation and controls (I&C), Chapter 4 invokes requirements that will affect their type, location, and configuration but notes that all requirements for instrumentation, including final sensors, are covered in Chapter 10. The staff did not identify any I&C requirements in Chapter 4 that conflict with NRC requirements. The staff's detailed evaluation of I&C design requirements is provided in Chapter 10 of this report.

2.2 Performance Requirements

Section 2.2 of Chapter 4 of the Evolutionary Requirements Document prescribes general design requirements that reflect the intent of the criteria in 10 CFR Part 50, Appendix A, as they apply to reactor systems. For example, Section 2.2.1 establishes the basic defense-in-depth principle for the ALWR by specifying two separate barriers against the release of fuel fission products: the fuel cladding and the reactor coolant pressure boundary. The other topics addressed in this section are pressure boundary integrity, negative power coefficient, freedom from power oscillations, margin for normal operation and transients, reactivity control reliability, shutdown margin, and criticality margin.

Power Oscillations

In the DSER for Chapter 4, the staff concluded that the requirements of Section 2.2.4 of Chapter 4 of the Evolutionary Requirements Document pertaining to freedom from power oscillations were inadequate. This section of the original Evolutionary Requirements Document required that the reactor core be designed to be controllable to compensate for power oscillations without exceeding specified fuel design limits. The staff concluded that it was not sufficient that the core be controllable, particularly if this would require operator action. The design should ensure that fuel safety limits will not be exceeded for any power oscillation, either because of physical limitations or because it is prevented by an automatic safety-grade system, such as a reactor scram or a power runback. This was identified as an open issue in the DSER.

Revisions to Chapter 4 have significantly enhanced the original requirements. Section 2.2.4 now requires that fuel safety limits not be exceeded for any power oscillation, without operator actions, through inherent characteristics or prevention by the reactor protection system. The staff concludes that this is acceptable; therefore, this DSER open issue is closed.

2.3 Equipment Design Requirements

Section 2.3 of Chapter 4 of the Evolutionary Requirements Document addresses materials, the reactor pressure vessel (RPV) and its internals, and core and fuel design.

2.3.1 Materials

Low-Temperature Overpressure Protection

Section 2.3.1.7 of Chapter 4 originally specified that the "RPV design shall be such that special protection systems and controls for low-temperature overpressure protection (LTOP) are not required." However, in the DSER for Chapter 4, the staff commented that maintaining a low nil ductility transition temperature (RT_{NDT}) did not eliminate the need for special LTOP. This was identified as a confirmatory issue in the DSER for Chapter 4. In response, EPRI replaced the specification in Section 2.3.1.7 with a reference to Chapter 5, and states that LTOP will be provided by the residual heat removal (RHR) pressure relief system. In addition, Section 5.2.3.3.2 of Chapter 5 has been revised to require that the minimum calculated end-of-life pressure relief setpoints for LTOP be considered in determining the RHR relief capacity. These revisions fully address the staff's concerns. Therefore, this DSER confirmatory issue is closed.

In addition, the requirement in Section 2.3.1.6 of Chapter 4 has been replaced by the following:

> Except for the core belt region in the PWR, the reactor pressure vessel shall be designed and fabricated such that the initial nil ductility transition temperature (RT_{NDT}) at the most limiting location is not greater than 10 °F. The initial RT_{NDT} in the PWR core belt region shall not exceed -20 °F. The calculated end-of-life (60 years of service) shift in RT_{NDT} caused by irradiation for core belt materials (calculated ΔRT_{NDT} as specified in Regulatory Guide 1.99) shall not exceed 30 °F for both the PWR and BWR.

In the DSER for Chapter 4, the staff discussed EPRI's requirements for LTOP as they relate to Generic Safety Issue (GSI)-94 and referenced the staff's evaluation in Section 5 of the DSER for Chapter 3. In the DSER for Chapter 4, the staff identified EPRI's requirements to address GSI-94 as an open issue. Because EPRI has relocated its requirements relating to the resolution of GSI-94 to Appendix B to Chapter 1 of the Evolutionary Requirements Document, the staff has addressed this issue in the corresponding section of Appendix B to Chapter 1 of this report. Therefore, this DSER open issue is closed.

Copper, Nickel, and Sulfur Content

In the DSER for Chapter 4, the staff identified the percentage of copper in reactor pressure vessel forging as a confirmatory issue. Section 2.3.1.2 of Chapter 4 of the Evolutionary Requirements Document has been revised to require a maximum of 0.03 percent copper in the core beltline forging of the PWR. Since EPRI has met its commitment to provide limits for copper content of the reactor pressure vessel (RPV), this DSER confirmatory issue is closed.

The nickel and sulfur content of the base metal and weld metal is an important parameter for determining embrittlement of the RPV materials due to irradiation. In Revision 4, EPRI revised the rationale portion of Section 2.3.1.2 of Chapter 4. This section now requires that nickel be controlled in accordance with the ASME Code materials specifications. Section 2.3.1.2 of Chapter 4 also limits the sulfur content in base materials and weld material to 0.015 percent. The staff concludes that these proposed revisions are acceptable.

Material Surveillance Program

Section 2.3.1.8 of Chapter 4 requires that a material surveillance program be established to monitor reactor vessel irradiation and its effect on the vessel material properties. In the DSER for Chapter 4, the staff stated that EPRI had committed to expand this requirement to state that the surveillance program will comply with 10 CFR Part 50, Appendix H, and American Society for Testing and Materials (ASTM) E-185. Adherence to the specifications in these documents provides assurance of the structural integrity of the reactor vessel throughout the plant life. In the DSER, the staff identified the reactor pressure vessel surveillance program as a confirmatory issue. EPRI revised Section 2.3.1.8 of Chapter 4 to state its commitment to ASTM E-185-82 and Appendix H. Since the revised requirement is acceptable and EPRI has met its commitment, this DSER confirmatory issue is closed.

Fracture Toughness Specimens

Section 2.3.1.8.1 of Chapter 4 includes requirements for insertion of surveillance capsules in the reactor vessel as part of a surveillance program for fracture toughness. In the DSER for Chapter 4, the staff stated that in response to a staff comment, EPRI had committed to add a requirement to determine fracture toughness using the J_{Ic} method in accordance with ASTM E-813. This was identified as a confirmatory issue. Since EPRI has revised Section 2.3.1.8.1 in accordance with its commitment, this DSER confirmatory issue is closed.

2.3.2 Vessel and Internals Design

The common requirements in Section 2.3.2 of Chapter 4 also cover items such as vessel fabrication, head seals and leakage monitoring, automated inservice inspections, refueling cavity seal, reactor bolting, and insulation. The staff concludes that none of these requirements conflict with NRC regulatory requirements.

60-Year Design Life

Section 2.3.2.1.1 of Chapter 4 specifies that the RPV and its nonremovable internals will have a design life of 60 years. Because the ALWR is expected to receive an additional 20 years of neutron irradiation beyond that of current operating plants, the staff concluded that an irradiation dosage limit for the RPV internals (including bolting) for the 60-year life of the plant should be provided. EPRI committed to add a statement requiring the plant designer to specify such a dosage limit based on data from operating nuclear plants. This was identified as a confirmatory issue in the DSER. The staff has verified that EPRI has revised Section 2.3.2.1.1 of Chapter 4 to require that the plant designer establish the irradiation dosage limits and/or stress and strain limits for the RPV internals (including bolting), based on applicable data from operating nuclear plants and/or materials test reactors for a design life of 60 years. Also, EPRI has revised Section 2.3.2.1.1 to require that the reactor vessel pressure boundary material meet the requirements of 10 CFR Part 50, Appendix G, throughout the design life. Therefore, this DSER confirmatory issue is closed.

Fatigue Design Criteria

Section 2.3.2.1.4 of Chapter 4 requires that RPV designs provide significant margin in meeting fatigue design criteria without compromising other aspects of the design. This margin is required to account for uncertainties in predicting reactor service cycles and conditions that include extended life and load-follow duty. The staff will evaluate the actual margin for acceptability during the its review of an individual application for FDA/DC.

Flow-Induced Vibration

Section 2.3.2.1.5, which EPRI added to Chapter 4, requires that the RPV internals be designed so that flow-induced vibration will not cause unacceptable damage to the fuel assemblies or the reactor vessel internal structures. Table B.1-2 in Appendix B to Chapter 1 of the Evolutionary Requirements Document contains an unconditional commitment to Regulatory Guide (RG) 1.20, "Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing." For reactor internals identified as a prototype as defined in RG 1.20, EPRI requires that the following programs be completed in accordance with a schedule that is also defined in RG 1.20 and that the results of the programs be documented.

- a vibration analysis program during the design phase
- a vibration measurement program during the preoperational startup testing phase
- an inspection program following the preoperational startup testing

For reactor internals identified as non-prototype, EPRI requires that the preoperational test programs be as defined in RG 1.20 for the applicable category of non-prototype configuration.

On the basis of the requirements in Section 2.3.2.1.5 in Chapter 4 and the commitment to RG 1.20 in Table B.1-2 of Chapter 1, the staff concludes that the combination of predictive analyses, tests, and post-test inspection provides adequate assurance that the ALWR reactor internals will, during their service life, withstand the flow-induced vibrations of the reactor without loss of structural integrity.

Refueling Cavity Seal

Section 2.3.2.7 of Chapter 4 contains requirements for the refueling cavity seal. The ALWR will have a permanent seal between the reactor pressure vessel and the surrounding refueling canal floor to permit flooding above the vessel during refueling. Use of a permanent seal will eliminate the critical path time and the personnel radiation exposure that would result during the installation and removal of a non-permanent pool seal during each refueling outage.

The common requirements in Section 2.3.2 of Chapter 4 cover i[illegible] such as core and fuel design, fuel handling, and resistance to pellet cladding interaction. The staff concludes that none of these requirements conflict with NRC regulatory requirements.

3 BWR REACTOR PRESSURE VESSEL AND INTERNALS

3.1 Definition

The reactor pressure vessel (RPV) is the major element of the reactor coolant system pressure boundary containing and supporting the reactor core and reactor internals. It also provides for reactor coolant supply and a floodable volume to keep the core covered. The internals provide the supporting elements and devices inside the RPV that, together with the reactor core, reactor coolant system, and RPV instrumentation, perform the function of nuclear steam generation.

Section 3 of Chapter 4 of the Evolutionary Requirements Document, together with the applicable portions of Section 2, provides the utility requirements for the RPV and its internals and instrumentation for the BWR version of the ALWR plant. The staff found that none of these utility requirements conflict with NRC requirements. However, several items deserve further discussion, as indicated below.

3.2 Performance Requirements

Section 3.2 of Chapter 4 of the Evolutionary Requirements Document specifies that "the RPV shall be capable of satisfying all functional requirements under normal and transient operating conditions as defined in Chapter 1." In addition, the RPV steam volume plus the steamline volume is required to be large enough so that the changes in RPV pressure with time, during normal operations and events, do not exceed values acceptable for safety and operational analyses. EPRI has specified that the RPV be larger in diameter than current BWR pressure vessels in order to accommodate the reactor internal pump (RIP) motors. Consequently, the RPV water inventory will be increased and its wall fluence will be lower.

With respect to the RPV internals, the performance requirements call for a configuration design that will provide stable natural circulation in the normal operating regions of the power-flow map. In addition, this design is to have the capability to transfer smoothly to the forced circulation regime following startup of the RIPs and to reestablish natural circulation following a trip of the RIPs. The purpose of these requirements is to minimize dependence on active systems and to provide greater margin for accommodating operating transient conditions.

3.3 Equipment Design Requirements

Section 3.3 of Chapter 4 of the Evolutionary Requirements Document covers equipment design requirements. Section 3.3.1.2 specifies that nozzles, safe-ends, thermal sleeves, and spargers will be designed for the full number of design life cycles without having to be replaced. The safe-ends are expected to eliminate pipe cracking as a result of intergranular stress corrosion cracking. For the feedwater nozzles and the core cooling nozzles, the safe-ends are to be of a "tuning-fork" design that has proven to be effective where thermal cycling occurs.

Section 3.3.1.4.2 of Chapter 4 requires that the main steamline flow limiters be part of the reactor steam outlet nozzles. One advantage of this combination is that the rate of steam flow into the containment following a steamline rupture would be reduced. It would also reduce the dynamic loads on reactor internals and containment structures.

Section 3.3.1.9.1 of Chapter 4 requires that a power-assisted machine be provided that can be placed on the RPV closure head. This machine will be remotely controlled to disconnect and remove vessel stud nuts. The objective of this requirement is to reduce the critical path refueling time by reducing the head-removal time.

Section 3.3.2.4.3 of Chapter 4 specifies that the feedwater sparger will be designed with top exit holes followed by flow guides to aim the feedwater radially inward. This design will prevent (1) reactor coolant from flowing back into the feedwater spargers and pipes, (2) temperature cycling with resultant cracking at low feedwater flow rates, and (3) water hammer in the feedwater piping.

Section 3.3.3.2.1 of Chapter 4 requires that several sets of RPV water level instrumentation be provided. One will be a wide-range set, consisting of four divisions with instrument taps located in each of four quadrants, that will provide signals for reactor protection and safety systems. This will permit the use of any two-out-of-four logic and eliminate "1/2 scram" situations (e.g., during instrument testing).

Section 3.3.3.3 of Chapter 4 requires that temperature measurement instrumentation be provided only if it is necessary for plant operating procedures (e.g., to monitor metal temperature differentials during plant startup and shutdown). Because of the improved RT_{NDT} of the ALWR, the rationale portion of this section in the original Evolutionary Requirements Document stated that thermocouples would not be required for protecting the RPV from brittle fracture; therefore, it might be possible to eliminate the thermocouples completely. However, in the DSER for Chapter 4, the staff recommended that protection of the RPV from brittle fractures not be eliminated because of improved material; hence, thermocouples and a materials surveillance program were necessary. This was identified as an open issue in the DSER.

In a letter dated December 21, 1991, EPRI submitted a proposed revision in which the statement that thermocouples may not be required for brittle fracture protection of the RPV was deleted from the rationale portion of Section 3.3.3.3. The intent of the requirements of Section 3.3.3.3 is to provide some thermocouples to assist operations, but to minimize their number to reduce plant maintenance. The staff concludes that this revision acceptably addresses its concern. Therefore, this DSER open issue is closed.

4 BWR CORE AND FUEL

4.1 Definition

The core and the fuel are required to generate heat up to a rated value throughout planned operating cycles, with sufficient margin and control to accommodate normal operations and the safety analysis events listed in Table 1.2-1 of Chapter 1 of the Evolutionary Requirements Document.

4.2 Performance Requirements

Section 4.2.1.2 of Chapter 4 of the Evolutionary Requirements Document contains requirements for core characteristics to ensure stable operation for all expected operating conditions. In the DSER for Chapter 4, the staff raised several concerns related to the use of analytic methods to prevent thermal-hydraulic instabilities. The staff recommended that attempts be made to prevent unstable operation by design, even in the "excluded region" of Figure 4.4-1, and that current methods should be used to establish margins for thermal-hydraulic stability after calculational uncertainties have been included. This was identified as an open issue in the DSER. EPRI's revisions to Chapter 4 to address this open issue have resulted in requirements that are considerably improved in this area. Section 4.2.1.2.2 now requires that operation beyond stability limits be prevented by an operationally proven, reliable control and instrumentation system. This control and instrumentation system is required to be capable of detecting all expected modes of instability and automatically reducing the reactor power sufficiently to return the reactor to a stable condition before fuel safety limits are exceeded. The staff concludes that these requirements are acceptable. Therefore, this DSER open issue is closed.

As part of its continuing generic study of thermal-hydraulic stability, the staff has raised concerns about thermal-hydraulic stability during an anticipated transient without scram (ATWS). The Evolutionary Requirements Document does not address stability performance during an ATWS. Therefore, the staff will review applications for FDA/DC to ensure that designers demonstrate that the thermal-hydraulic stability performance of the core during an ATWS is acceptable.

With regard to load following and maneuvering capability, Section 4.2.1.4.2 of Chapter 4 specifies that no preconditioning of the fuel will be required for maneuvering. EPRI explains that the intent of this requirement is to remove previous related limitations on plant maneuvering so that components and systems other than the fuel establish the plant maneuvering limits. The staff recognizes that this is a desirable objective; whether it can be approved for a specific plant will depend largely on the fuel design.

With regard to nuclear and thermal-hydraulic design, Section 4.2.1.6.2 of Chapter 4 specifies that the core design will provide for extended cycle operation at reduced power or with reduced feedwater temperature. Since operation with reduced feedwater temperature would result in less thermal-hydraulic stability, the benefits of extending cycle operation by reducing the feedwater temperature must be weighed against the undesirability of decreasing core stability. The staff will address this matter during its review of an application for FDA/DC.

Section 4.2.2 of Chapter 4 establishes performance requirements for fuel reliability, burnup, and lifetime. Included is a requirement that premature fuel failure that results from manufacturing defects be less than 1 per 50,000 fuel rods, with a goal of 1 per 100,000. The Evolutionary Requirements Document also states that recent industry experience has shown that 1 failure per 50,000 is an achievable reliability.

In addition, Section 4.2.2 of Chapter 4 specifies that the basic fuel mechanical design is to be capable of peak bundle-average burnups of at least 50,000 megwatt-days per metric ton of uranium (MWD/MTU). This burnup capability is stated to be consistent with present or expected near-term experience. On the basis of the specified burnup rate, the Evolutionary Requirements Document requires the fuel rods and fuel assembly structural components to be designed for a minimum core residence time of . years.

In a letter dated July 9, 1987, EPRI stated that its requirements in Section 4.2.2 of Chapter 4 and similar requirements for PWRs in Section 7.2.2 of Chapter 4 are sufficient to consider Generic Issue (GI) B-22 resolved for the ALWR. This issue was established to track industry efforts to improve the reliability of predictions of fuel performance during normal operations and postulated accident conditions. On the basis of current industry experience, there has been a substantial improvement in fuel reliability since GI B-22 was initiated. The staff is continuing to monitor fuel performance; however, it agrees with EPRI that GI B-22 is resolved for the ALWR.

4.3 Equipment Design Requirements

Section 4.3 of Chapter 4 of the Evolutionary Requirements Document provides BWR equipment design requirements for the core and fuel, neutron sources, and nuclear instrumentation. None of these conflict with NRC regulatory requirements.

Section 4.3.2.2.2 of Chapter 4 contains requirements for the core power distribution. The core power distribution will be monitored by both fixed power level in-core sensors and movable traversing in-core probe (TIP) detectors or fixed in-core calibration detectors. If the TIP system is used, the TIP drive mechanisms, guide tubes, and position indicators, including any necessary shielding and TIP motion interlocks, will be designed and located for ease of servicing and/or replacement. The TIP system has been the source of several overexposures or near overexposures (from exposure to irradiated in-core detectors and/or the attached TIP drive cables) in recent years during TIP withdrawal or replacement operations. To reduce personnel doses associated with TIP operations, the TIP interlock design will include appropriate alarm warnings and protective measures.

5 BWR CONTROL ROD DRIVE SYSTEM

5.1 Definition

The control rod drive (CRD) system will include the electrohydraulic control rod drives, rod drive motors, hydraulic control units, hydraulic supply system, scram and scram pilot solenoid valves, air header dump valves, interconnecting piping, and associated instrumentation, including rod position and separation sensors. In a BWR, the CRD system is required to perform the following functions:

- withdraw and insert the control rods at a normal rate for operational control
- control and indicate the positions of the control rods throughout the full stroke
- insert the control rods for shutdown (scram) at the high rate required to maintain fuel integrity
- control the positions of selected rods for core thermal-hydraulic stability control
- control the positions of ganged-rod groups for faster changes in rod position
- provide for the insertion of control rods by an alternative and diverse method on receipt of ATWS (anticipated transient without scram) signals
- supply measured purge water to the reactor internal pumps

5.2 Performance Requirements

Section 5.2 of Chapter 4 of the Evolutionary Requirements Document establishes performance requirements for the BWR CRD system. The staff found that none of these utility requirements conflict with NRC requirements.

Section 5.2.1.2 of Chapter 4 requires that limiting conditions for operation be developed to define the acceptable number and arrangement of CRDs that are found to exceed the maximum scram times during test or operation. The rationale for allowing the use of such CRDs is that a more precise calculation may be carried out by considering the actual performance of nearby control rods, measurement errors, and current core operating conditions. EPRI anticipates that this use of CRDs with scram times in excess of the maximum may help to meet the plant availability goals (i.e., 87-percent annual average over the life of the plant) without reducing safety.

Section 5.2.1.4 of Chapter 4 specifies that the scram performance and design of the CRD and hydraulic system will accommodate either a hafnium type or a boron carbide type of control rod. The hafnium-type control rods have slower scram times because they are heavier.

5.3 Equipment Design Requirements

Electric motor drives are specified in Section 5.3.1.1 of Chapter 4 of the Evolutionary Requirements Document for withdrawal and insert motion at normal speed. The rationale portion of this section indicates that this specification is based on favorable experience with electric motor drives in BWRs overseas. The ability to move rods in small increments permits more precise core power shaping and reduces the tendency for fuel cladding cracking associated with large increments. In addition, the use of electric motor drives enables simpler seals to be used and allows changing these without removing the CRDs.

Section 5.3.1.3 of Chapter 4 requires that the scram action of the CRD be achieved by water hydraulic pressure provided by gas-charged accumulators. It also allows each accumulator to provide scram pressure for several CRDs if the concept is adequately supported by a safety evaluation. EPRI states that this concept is being used successfully in overseas plants.

Section 5.3.5.3 of Chapter 4 requires that the scram pilot solenoid valves be designed for continuous operation at the minimum and maximum voltages and frequencies required by the reactor protection system (RPS). The rationale for this requirement is to avoid the overheating and consequent damage to valve materials observed in earlier plants. In a letter dated November 13, 1987, the staff asked EPRI if the scram pilot solenoid valves proposed in the Evolutionary Requirements Document were meant to replace the electric protective assemblies (EPAs) that were used in past BWR designs to prevent an overvoltage, undervoltage, or underfrequency condition from failing the scram pilot solenoid valves in a non-fail-safe state.

In its response dated January 25, 1988, EPRI described a failure mode involving the scram discharge volume (SDV) that had already been eliminated for the advanced boiling water reactor (ABWR) design, but was not the original reason for the addition of the EPAs. The failure mode identified by EPRI was the potential, in previous BWR designs, for a low-voltage condition that allowed some scram discharge valves to open and fill the SDV without a scram of all control rods. The original basis for requiring the EPAs, however, was the concern that an overvoltage, undervoltage, or underfrequency condition would cause excessive current or vibration of the scram pilot solenoid valves resulting in overheating and eventual lockup of these valves. Eliminating the SDV eliminates the failure mode identified by EPRI but not the failure mode identified by the staff.

In subsequent discussions with the staff, EPRI stated that the intent of this section of the Evolutionary Requirements Document was to preclude the overheating and binding of the solenoid valves by requiring that they be designed to operate continuously over the full range of voltages and frequencies that could be put out by the RPS power supplies. EPRI intends to demonstrate this through a failure modes analysis of the power supplies. In the DSER for Chapter 4, the staff stated that it did not believe that it was possible to demonstrate that there were no failure modes of the RPS power supplies that would result in a non-fail-safe failure of the scram pilot solenoid valves and identified this as an open issue.

In a letter dated February 11, 1992, EPRI continued to maintain that the function of the EPA was not needed because of the elimination of the SDV. As stated above, the staff maintains that eliminating the SDV does not eliminate the failure mode that was the original basis for the EPA function. Furthermore, EPRI's approach of specifying requirements for the power supplies and the scram pilot solenoid valves, while needed, does not eliminate the full range of postulated failures that resulted in the need for the EPA. Therefore, the staff has pursued the need for the EPA function with General Electric (GE) in the ABWR review. On the basis of preliminary discussions, it appears that GE has included the EPA in the ABWR design. Therefore, the staff concludes that this issue should be reviewed as part of an individual application for FDA/DC, and this DSER open issue is closed.

Section 5.3.6 of Chapter 4 requires an alternative means of rod insertion that is separate and diverse from normal scram by the reactor trip system. This is consistent with the NRC regulations in 10 CFR 50.62.

Maintenance

The objectives of the requirements in Section 5.3.9 of Chapter 4 are to reduce personnel radiation exposure during maintenance of CRDs and to reduce critical path time during refueling. To reduce personnel radiation exposure during maintenance of CRDs, a machine for automated removal and reinstallation of the CRDs will be used. Adequate working space will be provided below the CRD mechanisms to permit removal of the motors and maintenance on the shaft seals without having to remove the entire mechanism from the reactor. This will reduce both the time needed to perform the work and the resultant exposure incurred. In addition, temporary shielding will be used, if needed, to lower area dose rates during the removal and storage of CRD internals.

6 PWR REACTOR PRESSURE VESSEL AND INTERNALS

6.1 Definition

The PWR reactor pressure vessel (RPV) and its internals will provide a high-integrity pressure boundary containing the reactor coolant, reactor core, and fuel fission products. In addition, the RPV and internals will perform the following functions:

- provide support for fuel assemblies and maintain their orientation and position within the reactor core
- provide the necessary structure that will result in a flow path for the reactor coolant to adequately remove heat generated by the core while
  - ensuring proper reactor flow distribution
  - resisting upward flow-induced movement of the fuel assemblies
  - avo ding flow-induced vibration in core components (e.g., fuel rods, holddown springs and control rod assembly fingers)
  - ensuring positive location and guidance of control rod assemblies
  - ensur 'g that heat generated by each fuel assembly is removed by the reactor coolant
- provide information regarding the RP' water level during shutdown

6.2 Performance Re'''rements

In the DSER for Chapter 4, the staff stated th . Section 6.2.4 of the original Requirements Document included a requiremen ,t "appropriate analysis shall be performed to demonstrate the adequacy of reactor pressure vessel (RPV) for a natural circulation cooldown of the reac or from full power." The staff recommended that this requirement be revised to require the RPV to be able to withstand multiple cooldowns sufficient to resolve Generic Safety Issue (GSI) 79, "Unanalyzed Reactor Vessel Thermal Stress During Natural Convection Cooldown." This was identified as an open issue in the DSER.

In Revision 1 of Section 3.4.2.4 of Appendix B to Chapter 1 and in Section 6.2.1 of Chapter 4, EPRI clarified this issue by adding the following requirement: "A natural circulation cooldown transient shall be evaluated as part of Code vessel ev luations as an infrequent event which could occur at least 30 times over the 60-year life of the reactor pressure vessel." In the discussion of GSI 79 in NUREG-0933, "A Prioritization of Generic Safety Issues," dated December 31, 1984, the staff estimated that this event could occur 0.04 time per year, which would be only 2.4 times in 60 years. The staff's evaluation of EPRI's requirements to address GSI 79 is provided in Section 3.2.29 of Appendix B to Chapter 1 of this report. Therefore, this DSER open issue is closed.

6.3 Equipment Design Requirements

Section 6.3 of Chapter 4 of the Evolutionary Requirements Document gives equipment design requirements for the RPV, reactor internals, and RPV instrumentation. The staff found that none of these utility requirements conflict with NRC requirements. However, some of the items are of particular interest, as indicated below.

Section 6.3.1.1 of Chapter 4 requires that the RPV be supported by support pads welded to or forged integrally with the vessel at the flange or at the primary coolant nozzle elevation. Supporting the RPV in this manner is a design improvement, as compared with support from a lower head. EPRI states that thermal expansion stresses in the vessel nozzles and in the reactor coolant system (RCS) piping will be reduced. Thermal expansion displacement of the permanent refueling flange seal will also be reduced. In addition, if the support pads are integrally forged, the attachment welds will be eliminated, thus reducing inservice inspection requirements.

Reductions in refueling time and worker radiation exposure are expected to result from two requirements in Section 6.3.1.6 of Chapter 4. One of these requirements specifies that means will be provided to remotely detension and remove RPV studs and cover stud holes. Another requirement specifies capability for integrated head disassembly that will enable the entire head package and all related components to be lifted as a single unit. These design features would shorten refueling outages by simplifying several of the refueling outage tasks and would thereby result in lower personnel exposures.

Section 6.3.1.8 of Chapter 4 requires that the PWR refueling cavity seal be located as high as practicable on the reactor vessel so as to minimize the area of vessel material exposed to borated water. The seal is to be designed so that it is not susceptible to any single failure that could result in a rapid draindown of the refueling cavity.

Section 7.3.1.7.2 of Chapter 4 requires that the fuel assembly holddown force be sufficient to permit operation of all main coolant pumps at any temperature acceptable for running one or more main coolant pumps. The rationale given for this requirement is that temporary reductions in coolant temperature can be made during startup operations without the need to shut down a main coolant pump. This will reduce the possibility of a reactor coolant pump seal failure. The operation of all main coolant pumps at any temperature can also reduce plant heatup time. In Section 6.3.2.3, the hydraulic design requirements specify that the flow in the core peripheral region will be upward during all normal operating conditions. This will preclude an inward pressure gradient from the core baffles to peripheral fuel rods and thus will reduce the possibility of jet impingement on peripheral fuel assemblies.

Section 6.3.2.6.1 of Chapter 4 requires that the reactor upper internals and the lower internals (core support structures) each be removable as a unit using a vertical lift and no in-vessel disassembly will be required. This will simplify removal of the internals and allow for their maintenance, inspection, and repair.

Section 6.3.3.1 of Chapter 4 includes a requirement for permanently installed piping between the RCS and the pressurizer to eliminate inaccuracies in level monitoring during plant shutdowns. Such inaccuracies have been experienced in current plants that have temporarily installed tygon tubes; when the tube kinks, air is entrapped in the tube. During normal operation, the piping for the shutdown level monitoring system will be disconnected from the pressurizer and RCS by means of blind flanges.

In Appendix E of the DSER for Chapter 10, the staff evaluated an optimization issue submitted with Chapter 10 of the Evolutionary Requirements Document that presented arguments for not including requirements for a reactor vessel level instrumentation system (RVLIS) for evolutionary PWR designs. The staff concluded that EPRI's proposal to eliminate the RVLIS was unacceptable. In its response dated December 6, 1991, to the staff's DSER, EPRI included requirements for an enhanced RVLIS in Section 6.3.3.2 of Chapter 4. The staff concludes that this is acceptable; therefore, this issue is closed. The staff discusses this former optimization issue in Appendix B to Chapter 1 of this report.

7 PWR CORE AND FUEL

7.1 Definition

Section 7 of Chapter 4 of the Evolutionary Requirements Document defines the utility requirements for the PWR core and fuel. The components covered in this section include fuel assemblies, fuel rods, reactivity control devices, neutron sources, and core instrumentation.

The core and fuel are to generate heat up to a rated value throughout planned operating cycles, with sufficient margin and control to accommodate anticipated plant transients and planned maneuvers, all within defined limits. Section 2 of Chapter 1 specifies the transients and maneuvers to be considered.

7.2 Performance Requirements

Section 7.2.1.1 of Chapter 4 of the Evolutionary Requirements Document states that "calculations for regulatory licensing shall use methods approved by the NRC for the specific ranges of application and the most severe identified transients and acceptance criteria specified in Chapter 1, Section 2." The staff cautions that many of its approvals of correlations and codes have specific ranges of acceptability and the correlations and codes have only been approved for limited applications. It is important to stress that the calculational methods used must be approved by the NRC.

In the DSER for Chapter 4, the staff made the following comments related to Section 7.2.1.2, which EPRI was to consider in preparing future revisions of the Evolutionary Requirements Document:

- Although the staff has found that thermal-hydraulic oscillations are not a problem for current PWRs, this finding may have to be revalidated if the thermal-hydraulic characteristics of the evolutionary PWRs are sufficiently different from those of current PWRs.

- It is current staff practice to allow PWRs to have axially unstable, but not radially unstable, xenon oscillations.

- The staff should make certain that the thermal-hydraulic stability and radial xenon stability characteristics of new designs have been established by testing during its reviews of individual applications for FDA/DC. This was identified as an open issue in the DSER for Chapter 4.

In response to this DSER open issue, EPRI revised the Evolutionary Requirements Document to require that the thermal-hydraulic stability and xenon stability characteristics of new designs be verified by testing. The staff concludes that this is acceptable; therefore, this DSER open issue is closed.

Section 7.2.1.4.1 of Chapter 4 specifies that the core will be designed with the capability for load following and programmed load cycling without adjusting the soluble boron concentration during the maneuver. Moderator temperature would be changed in rapid response to small load changes, and low-worth control rods would be used to assist in programmed load-cycling control. Both of these mechanisms have been proven in operating PWRs. In the rationale portion of this section, EPRI states that "rodded maneuvering control without use of soluble boron is assessed to be feasible and practical with increased use of proven, low-worth control rod designs." This is not prohibited by NRC requirements.

Section 7.2.1.4.2 of Chapter 4 states: "The fuel shall be designed to avoid limitation on the rate of maneuvering capability and rate of power increase for hot startups of the plant.... Cold startup power restrictions due to fuel shall be eliminated." The staff recognizes the benefits of meeting this objective and will review the specific fuel designs during its review of individual applications for FDA/DC.

Section 7.2.2 of Chapter 4 addresses PWR fuel reliability, burnup, and lifetime in essentially the same terms as those in Section 4.2.2 for BWR fuel. The only apparent differences are associated with the specification of a minimum of 60,000 MWD/MTU average burnup for BWR fuel. These utility objectives are not prohibited by NRC requirements.

7.3 Component Design Requirements

The mechanical design requirements for the PWR core and fuel are given in Section 7.3.1.1 of Chapter 4 of the Evolutionary Requirements Document. They reflect the intent of the ALWR program to use proven designs. They also include such matters as designing the fuel to be debris resistant. None of these items are incompatible with NRC requirements.

Section 7.3.1.2.3 of Chapter 4, originally specified that the fuel cycle design include a non-positive moderator temperature coefficient (MTC) above 50-percent power at the beginning of life and for operation over the entire power range later in life. This requirement permits a positive MTC below 50-percent power at the beginning of life, which provides the flexibility to permit long fuel cycles, but retains the operational benefits of a non-positive MTC in the 50- to 100-percent power load cycling range.

Positive moderator coefficients are not prohibited by NRC requirements. However, the effect of allowing positive moderator coefficients must be evaluated throughout the fuel cycle for all transients and accidents, including anticipated transients without scram. In the DSER for Chapter 4, the staff concluded that Section 7.3.1.2.3 of Chapter 4 did not adequately define when in the fuel cycle the positive moderator coefficients would be allowed above 50-percent power and what requirements would be used to decide when a positive moderator coefficient was acceptable. This was identified as an open issue in the DSER. In response to this DSER open issue, EPRI revised the Evolutionary Requirements Document to require that the fuel cycle design include a non-positive MTC over the entire fuel cycle when the reactor is critical. The staff concludes that this is acceptable; therefore, this DSER open issue is closed.

Section 7.3.1.4 of Chapter 4 and Table 4.7-1 specify materials requirements for the PWR fuel assemblies, fuel rod cladding, and control rods and refer to the material requirements in Section 5 of Chapter 1. The staff concludes that these materials requirements serve to ensure that PWR fuel assemblies, fuel rod cladding, and control rods are compatible with their intended service conditions, and are, therefore, acceptable.

Other topics addressed in Section 7.3.1 of Chapter 4 include control of hydriding, fretting corrosion, fuel assembly holddown force, holddown springs, cladding collapse, fuel rod bow, and fuel assembly bow. The staff reviewed the EPRI requirements pertaining to these topics and did not identify any that were incompatible with NRC requirements.

Section 7.3.2 of Chapter 4 covers the utility requirements for neutron sources and instrumentation. None of them conflict with NRC requirements; however, several of particular interest are discussed below.

Section 7.3.2.1 of Chapter 4 requires that the reactor core be designed so that the initial startup and subsequent startups can be performed with an adequate neutron level signal on the out-of-core source range nuclear instruments. This avoids the need for special startup procedures that can result in a reduced plant capacity factor and provides adequate margin to allow for extended shutdown periods.

Section 7.3.2.3.1 of Chapter 4 requires the use of fixed in-core neutron detectors instead of movable in-core detectors for monitoring core power distribution. This will simplify plant equipment and reduce maintenance.

Section 7.3.2.4 of Chapter 4 specifies that thermocouples to monitor core outlet temperature should be placed integrally with the neutron detector string. This arrangement will simplify the instrumentation by eliminating the need for separate thermocouple penetrations and conduits.

8 PWR CONTROL ROD DRIVE SYSTEM

8.1 Definition

The PWR control rod drive (CRD) system is defined as the CRD mechanisms, position indicators, drive shafts, and electrical connectors. The control rods are covered in Section 7 of Chapter 4 of the Evolutionary Requirements Document. The power supplies, power cables, and breakers are covered in Chapter 11.

In a PWR, the CRD system is required to perform the following functions:

- position (withdraw and insert) the control rods in the core in response to commands from the rod control system
- release the control rods for gravity insertion into the core on power interruption in response to a reactor trip initiated from either manual or automatic reactor protection system controls at the required rate to maintain fuel integrity
- permit the latching and unlatching of the connection between the drive rod and the control rod assemblies

8.2 Performance Requirements

Service Life

Section 8.2.1 of Chapter 4 of the Evolutionary Requirements Document requires that the CRD system pressure boundary be designed for a service life of 60 years and establishes the following design and test criteria:

• safe shutdown earthquake	1 event
• operational scrams	1500
• test scrams	450
• pressure test	1 per year

In the DSER for Chapter 4, the staff reported: "The above criteria appear to be appropriate for a service life of 60 years. However, this proposed lifetime exceeds that of existing CRD mechanisms (CRDMs); hence, it is not known whether that goal can be achieved." This was identified as an open issue in the DSER. In a letter dated May 22, 1991, EPRI responded to the staff's comment by stating: "The Requirements Document establishes the above criteria which the CRD mechanisms must be qualified to meet. The common practice with these components is to perform lifetime testing to qualify them for the design lifetime. The requirements will be used as the basis for this testing and any design will need to be satisfactorily tested to meet the ALWR requirements." The staff concludes that this is an acceptable commitment; therefore, the DSER open issue concerning the service life of the CRDMs is closed. However, it should be noted that, as part of its review of individual applications for FDA/DC, the staff will perform detailed reviews of the results of design and testing programs that will be implemented in accordance with the above criteria to demonstrate that the CRDMs are qualified for a 60-year service life.

Scram Time

Section 8.2.2 of Chapter 4 requires that the CRD system be designed so that if power is interrupted to the CRD coils or motors, the control rods will be inserted by gravity from the fully withdrawn position to the fully inserted position within a predetermined scram time. That scram time must be such that the total time from sensor activation to completion of rod insertion satisfies the most restrictive accident analysis. The staff concludes that this requirement is compatible with NRC requirements.

The performance requirements also address the CRD response time, positioning control, and verification of rod positions. Safety and reliability are addressed in Section 8.2.4 of Chapter 4, which specifies that the CRD system will be designed so that no single failure of a component, structure, system function, or service function will prevent the CRD system from performing its safety-related function of preventing inadvertent rod drop and rod ejection. In addition, the CRDMs are to be designed to operate without coolant flow (air or water) for a minimum of 30 minutes. This capability will provide a reasonable period of time for restoring the system after a loss of the CRDM cooling system.

8.3 Equipment Design Requirements

Section 8.3 of Chapter 4 of the Evolutionary Requirements Document covers equipment design requirements including structural and mechanical considerations, materials, electrical and instrumentation design, and maintenance and testing. These utility requirements specify a variety of details intended to achieve high-quality design, reliable operation, and simplified maintenance. For example, Section 8.3.1.3 of Chapter 4 specifies that all CRDM seals are to be seal welded to prevent leakage of reactor coolant and are to be accessible for repair without removing any adjacent CRDMs. Similarly, the CRDM stator coils and all electrical parts are to be replaceable without breaking the primary system pressure boundary and without removing any adjacent CRDMs. None of the equipment design requirements are incompatible with NRC requirements.

9 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 4 of the Evolutionary Requirements Document for the design of reactor systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the plant-specific design, operation, and arrangement of the reactor systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the Standard Review Plan (SRP) (NUREG-0800), or provide justification or alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 4 of the Evolutionary Requirements Document specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose reactor systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 4 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

CHAPTER 5, "ENGINEERED SAFETY SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 5, "Engineered Safety Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 5 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering, Incorporated; Bechtel Power Corporation; Commonwealth Edison Company; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Sargent and Lundy; Stone and Webster Engineering Corporation; Westinghouse Electric Corporation; Yankee Atomic Electric Company; and EPRI.

On December 8, 1987, EPRI submitted Chapter 5 of the Evolutionary Requirements Document for staff review. By letters dated January 27, March 18, and April 4, 1988, the staff requested that EPRI supply additional information. EPRI provided the information in responses dated March 28, April 6, August 16, and September 15, 1988.

On February 28, 1990, the staff issued its DSER for Chapter 5 of the Evolutionary Requirements Document. On July 12, 1990, and April 9, 1991, the staff and EPRI met with the Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on Improved Light Water Reactors (LWRs) to discuss Chapter 5, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 5, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively. EPRI submitted additional information regarding Chapter 5 by letters dated October 18, 1990, and May 22, July 2, and December 2, 6, and 16, 1991.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 5 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 5

Chapter 5 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's requirements for the design of the engineered safety systems for ALWRs. Engineered safety systems are provided to prevent or mitigate the effects of a spectrum of postulated accidents.

The key topics addressed in the Chapter 5 review include EPRI-proposed design requirements for

- EPRI's ALWR public safety goal

- severe-accident prevention and mitigation
- severe-accident containment performance criteria
- hydrogen generation and control
- source-term issues
- fire protection
- high/low-interface design (intersystem loss-of-coolant accident (LOCA))
- anticipated transients without scram
- operation of residual heat removal (RHR) system with reduced reactor coolant system inventory
- station blackout
- core-concrete interaction - ability to cool core debris
- high-pressure core melt ejection
- equipment survivability
- inservice testing of pumps and valves
- resolution of certain generic safety issues

1.3 Policy Issues

During its review of Chapter 5 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 5 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) containment performance criteria for severe accidents (2.1)

(2) metal-water reaction and hydrogen generation and control during a severe accident (2.3 and 6.5.1)

(3) automatic standby liquid control system (4.2)

(4) effective distribution of boron injection (4.3)

(5) safety classification of containment spray system (4.4 and 7.2)

(6) suppression pool bypass leakage (4.5 and 7.2)

(7) suppression pool temperature-monitoring system (4.6)

(8) operation of RHR system with reduced reactor coolant system inventory (Generic Letter 87-12) (5.2)

(9) safety depressurization and vent system (5.4, 5.5, and 6.6.5)

(10) use of remote manual valves on essential lines that are not part of the engineered safety systems (6.2)

(11) containment isolation provisions for in-containment refueling water storage tank connections (6.2)

(12) Type C leak testing (6.2)

(13) Type B testing of air locks (6.3.2)

(14) Type C containment valve leak rate testing interval (6.3.3)

(15) interface requirements for fission product leakage control systems (6.4)

(16) control systems for radiolytically generated hydrogen (6.5.2)

(17) timing of igniter activation in the event of an accident (6.5.3)

(18) containment heat removal (6.6.3)

(19) functionability of fission product control systems during a severe accident (6.6.4)

(20) equipment survivability criteria for severe accidents (6.6.6)

(21) severe-accident management (6.6.8)

(22) dynamic effects of pipe breaks during severe accidents (7.2 and 8.1)

(23) main steam isolation valve leakage rate (7.2)

(24) containment leak rate (8.1)

(25) postaccident pH control (8.2 and Appendix B to Chapter 1)

(26) containment integrity check (Appendix B to Chapter 1)

(27) high/low-pressure interface design (Appendix B to Chapter 1)

(28) deletion of charcoal adsorbers (Appendix B to Chapter 1)

(29) BWR suppression pool fission product scrubbing (Appendix B to Chapter 1)

(30) timing of fission product releases into containment (Appendix B to Chapter 1)

Confirmatory Issues

(1) low-temperature overpressure protection (5.2)

(2) automatic/manual initiation of feedwater flow (5.3)

(3) use of liquid in Type C containment leak rate testing (6.3.3)

(4) actuation of the containment spray system (8.2)

(5) low-temperature overpressure protection (Appendix B to Chapter 1)

(6) 10 CFR Part 50, Appendix J local leakage testing (Appendix B to Chapter 1)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All but one of the issues identified in the DSER for Chapter 5 have been resolved. The one outstanding issue is a policy issue on which the staff has taken a position, but for which the Commission has not had the opportunity to provide guidance. The outstanding issue, with a reference to the appropriate section of this chapter given in parentheses, is listed below. The designator in front of the issue provides a unique identifier for it. The letter "E" indicates that the issue applies to the evolutionary plant design. The first number designates the chapter in which it is identified. The letter "O" designates that it is an open issue. The final number is the sequential number assigned to it in the chapter.

Open Issue

E.5.O-1 core debris coolability (6.6.2)

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of Chapter 5 given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.5.V-1 containment performance criteria for severe accidents (2.1)

E.5.V-2 metal-water reaction and hydrogen generation and control during a severe accident (2.3 and 6.5.1)

E.5.V-3 fire protection (2.5)

E.5.V-4 diesel generator start time (3.2)

E.5.V-5 detailed LOCA analysis concerning core spray for BWRs (4.1)

E.5.V-6 safety classification of containment spray system (4.4 and 7.2)

E.5.V-7 suppression pool bypass leakage (4.5 and 7.2)

E.5.V-8 suppression pool temperature-monitoring system (4.6)

E.5.V-9 intersystem LOCA (5.2)

E.5.V-10 operation of RHR system with reduced reactor coolant system inventory (Generic Letter 87-12) (5.2)

E.5.V-11 shutdown risk (5.2)

E.5.V-12 feed-and-bleed capability (5.4)

E.5.V-13 safety depressurization and vent system (5.4, 5.5, and 6.6.5)

E.5.V-14 use of remote manual valves on essential lines that are not part of the engineered safety systems (6.2)

E.5.V-15 Type C leak testing (6.2)

E.5.V-16 containment integrated leak rate testing (6.3.1)

E.5.V-17 Type A leak testing (6.3.1)

E.5.V-18 Type B testing of air locks (6.3.2)

E.5.V-19 use of water in Type C containment leak rate testing (6.3.3)

E.5.V-20 Type C containment valve leak rate testing interval (6.3.3)

E.5.V-21 control systems for radiolytically generated hydrogen (6.5.2)

E.5.V-22 design criteria for igniter system (6.5.3)

E.5.V-23 evaluation of igniter system (6.5.3)

E.5.V-24 method for determining load collapse of containment (6.6.1)

E.5.V-25 concrete containment analysis (6.6.1)

E.5.V-26 containment overpressure protection (6.6.3)

E.5.V-27 functionability of fission product control systems during a severe accident (6.6.4)

E.5.V-28 equipment survivability criteria for severe accidents (6.6.6)

E.5.V-29 accident management plan (6.6.8)

E.5.V-30 dynamic effects of pipe breaks during severe accidents (7.2)

E.5.V-31 main steam isolation valve leakage rate (7.2)

E.5.V-32 suppression pool design features (7.3)

E.5.V-33 containment leak rate (8.1)

E.5.V-34 postaccident pH control (8.2 and Appendix B to Chapter 1)

2 TOP-LEVEL REQUIREMENTS COMMON TO BWRs AND PWRs

EPRI intends the design bases of the ALWR to provide a balance between core damage prevention and core damage mitigation. The core damage prevention functions include (1) the core coolant inventory function, (2) the decay heat removal function, (3) the diverse reactivity control function, and (4) the reactor coolant system (RCS) pressure control function. The mitigation functions include (1) the containment integrity function and (2) the fission product control function. The engineered safety systems, in conjunction with supporting systems described in other chapters of the Evolutionary Requirements Document, serve to provide these functions. Sections 2.1 through 2.4 of Chapter 5 of the Evolutionary Requirements Document define top-level requirements applicable to both the core damage prevention and mitigation features of BWRs and PWRs.

2.1 ALWR Public Safety Goal

Section 2.2.2 of Chapter 5 of the Evolutionary Requirements Document states that probabilistic risk assessment (PRA) techniques will be used to demonstrate that the plant design will meet EPRI's ALWR safety margin basis goals as follows:

- Frequency of core damage is less than 1.0E-5 event per reactor-year.
- Whole-body dose at an assumed 0.5-mile site exclusion area boundary must be less than 25 rem for events whose cumulative frequency exceeds 1.0E-6 per reactor-year.

EPRI's basis for selecting 25 rem as the whole-body dose criterion is that it considers this value to be "a very low dose with no observable health effects." It considers the associated accident frequency of 1.0E-6 to be "low enough to satisfy the utilities' desire for excellence and the public perception," and believes that it can be demonstrated analytically.

The staff compared these objectives with the Commission's safety goal policy, which was announced on August 4, 1986 (51 FR 23044). In its safety goal policy, the Commission proposed as qualitative goals that the operation of a nuclear power plant should pose very low risks to nearby individuals and to society. In addition, the following quantitative objectives were to be used in determining achievement of these goals:

- The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities from a reactor accident should not exceed 0.1 percent of the sum of prompt fatality risks from other accidents.
- The risk to the population in the area near a nuclear power plant of cancer fatalities resulting from reactor operation should not exceed 0.1 percent of the sum of cancer fatality risks from all other causes.

In the DSER for Chapter 5, the staff stated that it was reviewing the proposed ALWR public safety goals to ensure they are consistent with the Commission's Safety Goal Policy Statement. The current regulations do not specify requirements in numerical terms of frequency of core damage or large release events.

When the DSER was issued, the staff recommended that the Commission approve the use of the following quantitative objectives in its implementation of the safety goal policy for future standardized plants:

- The mean core damage frequency target for each design should be less than 1.0E-5 event per reactor-year.

- The overall mean frequency of a large release of radioactive materials to the environment from a reactor accident should be less than 1 in 1 million per year of reactor operation for which a large release is defined as one that has a potential for causing an offsite early fatality.

Although these staff-proposed quantitative objectives were not part of the current regulations, the staff stated that they were consistent with the Commission's Safety Goal Policy Statement.

In its staff requirements memorandum (SRM) dated June 26, 1990, the Commission approved the use of an overall mean frequency of a large release of radioactive materials to the environment from a reactor accident that is less than 1 in a million per year of reactor operation. Although the current regulations do not specify requirements in numerical terms of frequency of core damage, the Commission, in its June 15, 1990, SRM on implementation of the NRC's safety goals, stated that "a core damage probability of less than 1 in 10,000 per year of reactor operation appears to be a very useful subsidiary benchmark in making judgments about that portion of [the NRC's] regulations which are directed toward accident prevention."

In its letter dated January 27, 1988, the staff requested that EPRI clarify its position regarding the ALWR public safety criterion so that the staff could determine if EPRI's second criterion, stated above, is consistent with this guideline. By letter dated April 6, 1988, EPRI responded that "the results of the PRA that is performed will be used to obtain a mean complementary cumulative distribution function (CCDF) for whole-body dose at 0.5 mile and to show that no point on this curve exceeds both 25 rem and 1.0E-6 per reactor-year." EPRI further stated that Appendix A to Chapter 1 of the Evolutionary Requirements Document, "PRA Key Assumptions and Groundrules," will address the methods for demonstrating that a design has met the proposed criterion. In addition to designing an ALWR to meet its public safety goal, EPRI also requires the designer to show that the facility meets the dose guidelines of 10 CFR Part 100 for the limiting design-basis accidents. The staff's review of Appendix A to Chapter 1 is provided in the corresponding chapter of this report.

In a letter dated April 6, 1988, EPRI indicated that the ALWR public safety goals do not contain explicit criteria for conditional probability of containment failure or other mitigation features, since EPRI believes that such criteria could potentially distort the balance in safety design and inhibit innovative improvements in core protection features. The letter cites the consistency of this position with the conclusions stated in the Nuclear Management and Resources Council (NUMARC) Containment Integrity Working Group report dated February 3, 1988.

In the DSER for Chapter 5, the staff stated that it believes that a fundamental principle of safety, defense-in-depth, is based on the concept that multiple barriers should be provided to ensure the integrity of those barriers to prevent any significant release of radioactivity. In its Severe Accident Policy Statement, the Commission indicated that it "fully expects that vendors engaged in designing new (or custom) plants will achieve a higher standard of severe-accident safety performance than their prior designs." A defense-in-depth approach reflects an awareness of the need to make safety judgments in the face of uncertainties; in effect, not putting all the eggs in one basket. In that regard, the reactor containment boundary should serve as a reliable barrier against fission product release for credible severe-accident phenomena/challenges. Every effort should be made to eliminate or further reduce the likelihood of a release sequence that could bypass the containment. The continued reliance on the traditional principle of containment of fission products following an accident is seen as the logical and prudent approach to addressing reasonable questions that will persist regarding our ability to accurately predict certain aspects of severe-accident behavior. To ensure a balance between prevention and mitigation, some criteria on containment performance are appropriate. Accordingly, a general goal of limiting the conditional containment failure probability to less than 1 in 10 when weighted over credible core damage sequences would constitute appropriate attention to the defense-in-depth philosophy.

PRA is a very powerful tool that permits systematic, integrated assessment of design strengths and weaknesses. However, because very-low-frequency scenarios (approximately 1.0E-6 per reactor-year) are being addressed, it is important to keep in perspective the very large uncertainties in the quantification of these scenarios. The overall uncertainties in severe-accident behavior are driven largely by insufficient data for assessing common-cause failures, difficulty in quantifying of the potential for human errors, and questions about completeness of analyses and uncertainties in phenomenological behavior. For this reason, the staff considers it acceptable to use a deterministic containment performance criterion that would provide a level of containment performance comparable to that which could be demonstrated using a probabilistic containment failure goal of 10 percent, given a severe accident.

The containment function (i.e., maintenance of a leak-tight barrier against radioactivity release) would be distinctly challenged by a severe accident. Those challenges may be roughly divided into two categories: energetic or rapid energy releases and slower, gradually evolving releases to the closed containment system. Examples of containment loadings that fall into the first category include high-pressure core-melt ejection with direct containment heating, hydrogen combustion, and the initial release of stored energy from the reactor coolant system. Slow energy releases within the containment are typified by decay heat and noncondensible gas generation. Engineering practice in containment design calls for providing passive capability in dealing with energetic energy releases, where practicable, while long-term energy releases may be controlled by both passive means and through active intervention. On this basis, the staff concluded in the DSER for Chapter 5 that the following general criteria for containment performance during a severe-accident challenge are appropriate for evolutionary ALWRs with steel containments:

The containment should maintain its role as a reliable leak-tight barrier by ensuring that containment stresses do not exceed ASME Service Level C limits for a minimum period of 24 hours following the onset of core damage.

The staff further concluded that the containment stresses for evolutionary ALWRs with concrete containments should not exceed the ASME factored load category for a minimum of 24 hours following the onset of core damage.

Maintaining containment integrity for the first 24 hours is based on providing sufficient time for the remaining airborne activity in the containment (principally noble gases and iodine) to decay to a level that would not exceed 10 CFR Part 100 dose guidelines when analyzed realistically, if controlled venting were to occur after that time. During this 24-hour period, containment integrity should be provided, to the extent practicable, by the passive capability of the containment itself and any related passive design features (e.g., suppression pool). The staff further concluded that following this 24-hour period, the containment should continue to provide a barrier against the uncontrolled release of fission products. However, in keeping with the concept of allowing for intervention in coping with long-term or gradual energy release, the staff stated that, after 24 hours, controlled, elevated venting may be used in the containment design to reduce the probability of a catastrophic failure of the containment. Alternatively, diverse containment heat removal systems could be used or the restoration of normal containment heat removal capability could be relied on, if sufficient time is available for major recovery actions (e.g., 48 hours). Systems used to prevent long-term containment failure need not meet the full complement of regulatory requirements associated with safety systems. The design of those systems need only ensure an appropriate reliability for operation. Furthermore, accident-mitigation features that deal with core-damage accidents can be evaluated on a best-estimate basis.

In evaluating the capability of the containment design, it is necessary to consider the energy loading associated with (1) stored energy from the RCS, (2) chemical reaction energy associated with core degradation, (3) decay heat, and (4) hydrogen combustion and other noncondensible gas generation, as appropriate, including core-concrete interaction consistent with the design. The staff concluded that other energy release mechanisms (e.g., direct heating) should be addressed by reducing their likelihood to sufficiently low levels through design features.

In the DSER for Chapter 5, the staff concluded that the design features to maintain the integrity of the containment against such challenges would lead to a rugged containment system. In view of the low probability of accidents that would challenge the integrity of the containment, the staff concluded that the unreliability of the mitigation systems, from the onset of core damage to prevention of significant releases, should not exceed approximately 0.1.

However, the staff intends to ensure that the containment can deal with all credible challenges and does not intend to apply the conditional containment failure probability (CCFP) guideline in a manner that could be interpreted to potentially detract from overall safety. The staff stated that it will accept a CCFP of 0.1 or a deterministic containment performance goal that offers comparable protection in its evaluation of the evolutionary LWRs.

EPRI's ALWR public safety goals do not contain explicit criteria for CCFP. In lieu of requiring the inclusion of a CCFP goal in the Evolutionary Requirements Document, the staff concluded in the DSER for Chapter 5 that EPRI should include and justify an explicit measure of containment performance during a severe accident.

In its letter dated December 16, 1991, EPRI stated that its overall containment performance requirements ensure a robust containment for ALWRs. The containment will be designed to be capable of accommodating, without failure, severe-accident releases that are risk significant. Section 6.6.2.2 of Chapter 5 states that the criteria to be used by the plant designer will meet ASME Section III Service Level C or factored load limits.

The staff concludes that EPRI's position is consistent with the deterministic containment performance goal as stated in SECY-90-016 to the extent to which containment performance can be evaluated at the general level of the Evolutionary Requirements Document. Therefore, this DSER open issue is closed. However, to completely evaluate the merits of a containment design and the corresponding containment performance, a specific design is required. The staff will review an individual application for FDA/DC to the criteria in SECY-90-016.

2.2 <u>Station Blackout</u>

Section 2.3.3 of Chapter 5 of the Evolutionary Requirements Document requires the ALWR to be capable of maintaining a safe condition during a blackout (loss of ac power) for 8 hours. EPRI defined a safe condition for station blackout as a plant condition in which the reactor is subcritical, the core is covered with water, and no design limits have been exceeded. EPRI stated that the designer will use mechanistic system performance and best-estimate analytical methods to verify this capability. The staff was initially concerned that these analytical techniques may not be conservative enough when used in an 8-hour coping analysis to provide the necessary assurance that an ALWR can meet the requirements of the station blackout rule (10 CFR 50.63).

In a letter dated September 15, 1988, EPRI stated that a separate coping analysis will be conducted to confirm compliance with the station blackout rule. The analytical methodology for this analysis will be consistent with the guidance provided in NUMARC 8700 and Regulatory Guide (RG) 1.155, "Station Blackout." The staff endorses the use of these documents for the station blackout analysis and concluded that EPRI's commitment was acceptable. However, Chapter 11 of the Evolutionary Requirements Document also requires provision of a non-safety combustion turbine-generator capable of coping with a station blackout, which will provide a second means of coping with a station blackout. The use of the combustion turbine-generator is referred to as an alternate ac source in 10 CFR 50.63 and is one of the options allowed under that rule for meeting the station blackout requirements. The staff's position on this issue is that an alternate ac power source should be the preferred method of demonstrating compliance with 10 CFR 50.63 in evolutionary plant designs. If the alternate ac power source is the method used for demonstrating compliance with 10 CFR 50.63 and it is capable of bringing the plant to a cold shutdown (as specified by EPRI) in the same manner as the emergency diesel generators, the coping analysis provided with this approach should be minimal (possibly only limited to analysis of the capability of the combustion turbine-generator to power its loads for the duration of the station blackout). In any case, the staff expects whatever manner of analysis is provided to demonstrate compliance with 10 CFR 50.63 to be consistent with the guidance provided in NUMARC 8700 and RG 1.155.

Because determination of the actual coping duration and the ALWR capability to recover during that period is partially dependent on site-specific characteristics, the subject station blackout analysis required to show compliance with 10 CFR 50.63 will necessarily be plant specific. Additional requirements that address station blackout are provided in Chapter 11 of the Evolutionary Requirements Document. The staff's evaluation of these requirements are in the corresponding chapter of this report.

2.3 Zirconium-Water Reaction and Hydrogen Generation

In its letter dated August 16, 1988, EPRI stated: "Because of the mul[illegible]li-[illegible]y of regulatory requirements regarding hydrogen control for severe accidents, the specific regulation that the ALWR is required to meet [illegible]t clear at this time." On that basis, EPRI submitted the proposed ALWR h[illegible]ogen control requirements as an optimization issue, asking the staff to evaluate the proposed requirements on the basis of their unique technical merits independent of current and future regulations.

Section 2.4.1.7 of Revision 0 of Chapter 5 of the Evolutionary Requirements Document specified that containment and combustible gas control systems be designed to accommodate 75-percent in-vessel zirconium-water reaction of the active fuel cladding and 13-percent containment uniform hydrogen concentration. It stated that 75-percent cladding oxidation is believed to be a conservative upper limit on the amount of hydrogen generated in a degraded-core situation, including recovery. EPRI stated that no significant ex-vessel hydrogen generation, as a result of core-concrete interaction, would occur under severe-accident conditions.

In the DSER for Chapter 5, the staff stated that the proposed zirconium-water reaction assumption of 75 percent is considerably greater than the value prescribed by RG 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident," for design-basis-accident considerations and is believed to be a mid-range estimate of in-vessel hydrogen generation for severe accidents (see NUREG-1150, "Reactor Risk Reference Document," February 1987, Tables J.4.1 and J.4.2). The staff further stated that the proposed 13-percent hydrogen concentration limit is based on theory and extrapolations of experimental data described in Task 8.3.5.4, "Technical Support for the Hydrogen Contr[illegible] Requirement for the EPRI Advanced Light Water Reactor Requirements Document" (Fauske and Associates, Inc., June 1988). It is asserted to be very unlikely that detonations in hydrogen-air-steam mixtures will occur below this limit. However, because of the uncertainties in the phenomenological knowledge of hydrogen generation and combustion, the staff stated that, as a minimum, ALWRs should be designed to (1) accommodate hydrogen equivalent to 100-percent metal-water reaction of the fuel cladding and (2) limit containment hydrogen concentration to no greater than 10 percent. The staff's position is consistent with the requirements of 10 CFR 50.34(f) as referenced in 10 CFR Part 52. Furthermore, because hydrogen control is necessary, given present analytical capabilities, to preclude local concentrations of hydrogen to detonable limits, the staff concludes ALWRs should provide containment-wide hydrogen control (e.g., igniters, inerting) for severe accidents. Additional advantages of providing hydrogen control mitigation features (rather than relying on random ignition of richer mixtures) include the lessening of pressure and temperature loadings on the containment and essential equipment.

In its SRM of June 26, 1990, the Commission stated that the requirements of 10 CFR 50.34(f)(2)(ix) should remain unchanged for evolutionary LWRs.

Sections 2.4.1.6 and 2.4.1.7 of Revision 1 of Chapter 5 stated that the plant designer should ensure that a detonable mixture will not exist for an amount of hydrogen equivalent to that generated by oxidation of 75 percent of the fuel cladding surrounding the active fuel, and that the uniformly distributed gas concentration in the containment will not exceed 13 percent under dry conditions. Section 6.5 of Chapter 5 provides additional requirements using this criterion for combustible gas control. In its letter of December 6, 1991, EPRI stated that the Evolutionary Requirements Document will be modified to fully comply with the staff position of 100-percent active fuel cladding and a maximum containment concentration of 10 percent. The staff's position is that the plant-specific designs must comply with the provisions in 10 CFR 50.34(f) for combustible gas control as stated in SECY-90-016.

The staff concludes that EPRI has indicated its intent to comply with the staff position. Therefore, the DSER open issue is closed. The staff will evaluate the design against the criteria in 10 CFR 50.34(f) and SECY-90-016 during its review of an individual FDA/DC application. Additional information concerning the staff's position regarding acceptable implementation of these requirements is given in Section 6.5.1 of this chapter. Section 4 of Appendix B to Chapter 1 of this report provides additional cross-reference where this issue is discussed.

2.4 Decay Heat Calculations (American Nuclear Society (ANS) 5.1)

Section 2.2.6 of Chapter 5 of the Evolutionary Requirements Document states that the design of decay heat removal systems (excluding analyses performed in accordance with Appendix K to 10 CFR Part 50) will be based on decay-heat-generation rates as given in ANS 5.1 (October 1979). The staff concludes this is acceptable for realistic evaluations permitted by the revised 10 CFR 50.46 and Appendix K to 10 CFR Part 50.

Standard Review Plan (SRP) Section 9.2.5, "Ultimate Heat Sink," states that the design of decay heat removal systems should be evaluated against Branch Technical Position (BTP) ASB 9.2, which requires an additional 20-percent uncertainty factor be included for the first 1000 seconds following shutdown and 10 percent between 1000 seconds and 10 million seconds. However, a recent comparison to the ORIGEN code (described in an attachment to EPRI's letter of August 16, 1988) has shown ANS 5.1 to be a conservative predictor of decay heat generation. On this basis, the staff concludes that ANS 5.1 can be used in lieu of BTP ASB 9.2 for decay-heat-generation rates in the design of decay heat removal systems.

2.5 Fire Protection

Section 2.3.2 of Chapter 5 of the Evolutionary Requirements Document indicates that fire protection will be as specified in 10 CFR 50.48. It states that, for equipment in the same general area, a 3-hour fire barrier will be utilized in lieu of physical separation unless it is "impractical or less safe." In the DSER for Chapter 5, the staff stated that fire issues that have been raised through operating experience and through the External Events Program must be resolved for ALWRs. To minimize fire as a significant contributor to the likelihood of severe accidents for advanced plants, the staff concluded that current NRC guidance must be enhanced. Therefore, the criteria delineated in the Evolutionary Requirements Document must ensure that safe shutdown can be achieved, assuming that all equipment in any one fire area will be rendered inoperable by fire and that reentry into the fire area for repairs and operator actions is not possible. Because of its physical configuration, the control room is excluded from this approach, provided an alternative shutdown capability that is physically and electrically independent of the control room is included in the design. The ALWR design criteria must provide fire protection for redundant shutdown systems in the reactor containment building that will ensure, as much as practicable, that one shutdown division will be free of fire damage. Additionally, criteria should be provided in the Evolutionary Requirements Document to ensure that smoke, hot gases, or fire suppressants will not migrate into other fire areas to the extent that they could adversely affect safe-shutdown capabilities, including operator actions. Because the layout of a nuclear plant is design specific, the staff will review plant-specific design details on an individual basis. The staff will require a description of safety-grade provisions for the fire protection systems to ensure that the remaining shutdown capabilities are protected, as well as demonstration that the design complies with the migration criteria discussed above.

In SECY-90-016, the staff proposed that the above enhanced fire protection criteria be implemented for ALWR designs. In its SRM of June 26, 1990, the Commission endorsed these criteria as supplemented by the staff's response of April 27, 1990, to the ACRS comments. The staff's evaluation of EPRI's proposed requirements for fire protection is given in Section 3 of Chapter 9 of this report. Additional discussion regarding the enhanced fire protection discussed above and in Chapter 9 is contained in the regulatory analysis in Appendix B to Chapter 1 of this report.

2.6 Severe-Accident Analyses

Section 2.4.2 of Chapter 5 of the Evolutionary Requirements Document specifies that provisions be made and realistic analyses be conducted for severe accidents, including in-vessel and ex-vessel core-debris cooling and cavity flooding. The staff accepts the position that severe-accident analyses should be based on realistic or best-estimate methods with proper consideration of uncertainties in phenomenological modeling. In the absence of detailed, explicit regulatory criteria, the Evolutionary Requirements Document states that the plant designer will use industry-developed methods (e.g., MAPP) to demonstrate that the risk objectives of the ALWR public safety goal are met. The staff will, as appropriate, conduct independent analyses using staff-developed methods to assess each applicant's analyses. See Section 6.6 of this chapter for an evaluation of severe-accident mitigation features.

2.7 Source-Term Issues

Appendix C to Revision 0 of Chapter 5 contained EPRI-proposed requirements for specific source-term issues. EPRI's requirements regarding these issues are now in Section 2.5.2 of Appendix B to Chapter 1 and Section 1.2.3 of Chapter 5 of the Evolutionary Requirements Document. The staff's evaluation of these issues is given in Section 2.5.2 of Appendix B to Chapter 1 of this report.

3 ALWR CORE DAMAGE PREVENTION REQUIREMENTS

Prevention of core damage will rely on four functions: (1) core coolant inven-tory control, (2) decay heat removal, (3) diverse reactivity control, and (4) reactor coolant system (RCS) pressure control. Requirements to prevent core damage are applicable to both PWRs and BWRs and are defined in Section 3 of Chapter 5 of the Evolutionary Requirements Document.

3.1 Inservice Testing

In SECY-90-016 and in the DSER for Chapter 5, the staff stated that the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," has been used to establish past testing requirements for ASME Code Classes 1, 2, and 3 safety-related pumps and valves. Although these requirements provide certain information on the operational readiness of the components, they do not necessarily provide for the verification of the capability of the components to perform their intended safety function. Therefore, the code does not ensure the necessary level of component operability that is desired for the evolutionary LWR designs. The staff concluded that the following aspects of pump and valve testing and inspection are necessary to provide an adequate level of assurance of operability and should be applied to all safety-related pumps and valves and not be limited to ASME Code Classes 1, 2, and 3 components.

- Piping design should incorporate provisions for full-flow testing (maximum design flow) of pumps and check valves.
- Designs should incorporate provisions to test motor-operated valves under design-basis differential pressure.
- Check valve testing should incorporate the use of advanced nonintrusive techniques to address degradation and performance characteristics.
- A program should be established to determine the frequency necessary for disassembly and inspection of pumps and valves to detect unacceptable degradation that cannot be detected through the use of advanced non-intrusive techniques. The staff notes that current state-of-the-art non-intrusive techniques are insufficient to preclude disassembly and inspection of any pumps or valves. Therefore, with the current non-intrusive techniques, it will be necessary to determine a frequency for disassembly of all these components.

Section 3.4.1 of Chapter 5 of the Evolutionary Requirements Document requires systems to be inspectable and testable. In its letter dated April 4, 1988, the staff stated its position that plant designs for which the final design is not complete will have sufficient lead times during the development of the piping system designs to include provisions for inservice testing of all applicable pumps and valves in accordance with ASME Code, Section XI. Therefore, requests for relief from such testing should be virtually eliminated. The staff also informed EPRI of staff positions relating to inservice testing of check valves, valves in the emergency diesel generator subsystem, pressure isolation valves, solenoid-operated valves, excess flow check valves, and control rod drive valves.

In its letter dated August 16, 1988, EPRI responded that Chapter 1 will be revised to include specific requirements for inservice testing of valves in the emergency diesel generator subsystem. The staff's evaluation of this issue is in Chapter 1 of this report. For the purposes of this chapter, this issue is closed.

EPRI stated that the information requested on inservice testing of check valves, solenoid-operated valves, excess flow check valves, and control rod drive valves was beyond the scope of the ALWR Requirements Document and that the applicant will implement the inservice testing program at the time of licensing. The staff agrees with EPRI's response and will review the detailed inservice testing prepared for each plant design.

The staff's evaluation regarding leak testing of pressure isolation valves is given in Section 3 of Appendix B to Chapter 1 of this report.

3.2 Diesel Generator Start Time

Section 3.4.6 of Chapter 5 of the Evolutionary Requirements Document requires that engineered safety systems be designed so that the onsite power source start time need not be shorter than 20 seconds and the combined start time and load sequencing time need not be shorter than approximately 40 seconds. In the rationale portion of this requirement, EPRI stated that operating plants have sometimes exceeded the current 10-second start-time requirement by a few seconds or have experienced governor stability problems and emergency overspeed shutdowns. The staff questioned how the design of the diesel starting system might be changed to take advantage of this increased starting time and improve the starting reliability of the machine.

EPRI responded that a 20-second starting time improves diesel generator reliability by alleviating the requirements for the governor characteristics and eliminating most of the instability problems. It also allows the use of a ramp generator to control the acceleration of the unit to full speed. With this scenario, the unit accelerates freely up to approximately 50-percent speed, at which point the governor controls the acceleration to full speed following a predetermined ramp, thereby eliminating any overshoot. With the use of the ramp generator, the engine will safely reach full speed in 13 to 14 seconds. A 6- to 7-second margin is provided before load sequencing to allow lube oil pressure to build up and stabilize, which eliminates a failure to start because of a trip on low lube oil pressure. In addition, this margin ensures that all parts of the engine are properly lubricated before any large load is applied, thereby reducing engine wear.

The staff concludes that the longer starting period allowed for the diesel generator will likely improve the reliability for those conditions at which it is directed, assuming that the sequencing-on of the engineered safety system loads can be delayed with no adverse effects on the functional capability of the respective systems. Also, the amount of unreliability added by the ramp generator circuitry in the diesel generator must be considered.

The use of increased starting and loading intervals is acceptable, provided the increased intervals are properly incorporated into plant-specific accident analyses and shown by such analyses to result in acceptable consequences. The staff will require the ALWR designer/applicant to demonstrate the acceptability of such an analysis during the staff's review of an individual application for FDA/DC.

3.3 Electric Valve Operators

Section 3.4.12 of Chapter 5 of the Evolutionary Requirements Document stated that valve operator motor controls will generally not be designed to automatically stop valve motion as a result of an electric overload except during valve operational testing. This requirement was in general agreement with Position 1(a) of RG 1.106, "Thermal Overload Protection for Electric Motors on Motor-Operated Valves" (Revision 1), which states that thermal overload protection devices should be continuously bypassed and used temporarily only when the valve motors are undergoing periodic or maintenance testing. The specified requirement is acceptable; however, it conflicted with the requirements in Sections 6.5.2 and 7.6.1 of Chapter 11 of the Evolutionary Requirements Document, which specify that thermal overloads for valve motors will be used to trip the operator when necessary to prevent motor failure and provide an alarm indicating misoperation. In a letter dated January 10, 1992, EPRI stated that its approach for providing valve operator protection without compromising the safety functions is that described in Chapter 11 and, to eliminate any ambiguity, Section 3.4.12 of Chapter 5 will be deleted. The staff concludes that this is acceptable. This paragraph was deleted in Revision 4 of Chapter 5. This issue is also discussed in Section 2.2.9 of Chapter 11 of this report.

4 BWR CORE DAMAGE PREVENTION REQUIREMENTS

The Evolutionary Requirements Document states that the BWR core coolant inventory control, decay heat removal, and reactor coolant system (RCS) pressure control functions will be provided by the following systems in the ALWR design:

- high-pressure injection (HPI) system
- reactor core isolation cooling (RCIC) system
- decay heat removal (DHR) system
- automatic depressurization system (ADS)

These systems are grouped into three divisions, each division having independent service water, ac power, and dc power supplies. Divisions 1 and 2 will be identical; each will have a motor-driven high-pressure injection pump and one or more motor-driven low-pressure DHR pumps. Division 3 will consist of a steam-driven high-pressure injection pump, an ADS, and a DHR pump. Each division will have a heat exchanger. Any of the three divisions will be capable of performing the low-pressure injection or suppression pool cooling function. Two of the divisions will provide containment spray.

4.1 Elimination of Core Spray

The ALWR BWR design does not include a core spray system because EPRI believes that reflood cooling is sufficient to protect against core damage. In addition, this design eliminates the concern of a large or medium loss-of-coolant accident (LOCA) below the core because the large recirculating system piping has been removed. The staff concludes that this design is acceptable if detailed LOCA calculations confirm that core spray is not necessary to meet 10 CFR 50.46 requirements. The staff will require the ALWR designer/applicant to demonstrate the acceptability of such an analysis during the staff's review of an individual application for FDA/DC.

4.2 Anticipated Transients Without Scram

In its DSER for Chapter 5, the staff stated that the Evolutionary Requirements Document did not specify a requirement for an automatic pump trip to resolve staff concerns regarding anticipated transients without scram (ATWS) for ALWR BWRs. The staff concluded that this requirement should be added or exemption from the ATWS rule (10 CFR 50.62) should be justified.

In its letter dated December 6, 1991, EPRI agreed to provide a requirement for an automatic initiation feature for the standby liquid control system (SLCS). Section 4.6.3.5.1 of Revision 4 to Chapter 5 includes this modification. The staff concludes that this requirement is in accordance with 10 CFR 50.62 and is acceptable. Therefore, this DSER open issue is closed. This issue also is discussed in Section 2.5.4 of Appendix B to Chapter 1 of this report.

4.3 Standby Liquid Control System

The diverse reactivity control function required by General Design Criterion (GDC) 26 of Appendix A to 10 CFR Part 50 is provided by the SLCS. The ALWR proposed design is similar to the SLCS in current BWRs. The system performance requirement in Section 4.6.2 of Chapter 5 of the Evolutionary Requirements Document states that the amount of sodium pentaborate and its minimum injection rate will be sufficient to bring the reactor from full rated power to cold shutdown and hold it there with sufficient margin to allow for xenon decay. The design should be sufficient to allow for mixing and dilution by the shutdown cooling water. Since a 13-percent solution of sodium pentaborate will be used, adequate heating means must be provided to maintain solution temperature above its saturation temperature and prevent precipitation.

The sodium pentaborate solution is injected into the reactor vessel through the high- and low-pressure safety injection lines. It was determined experimentally that this method of injection will provide good mixing of the injected fluid with the reactor vessel water. In addition to differing from existing facilities in the means of injection to the vessel, this pump discharge path also differs from previous designs by not including explosive squib valves in the pump discharge lines. The zero-leakage capability of squib valves is not necessary for this system design because the SLC pumps and piping are not normally in contact with the sodium pentaborate solution. The motor-operated valves realign to provide suction and discharge paths for the pentaborate solution when the SLCS is initiated. The staff concludes that the design criteria proposed by EPRI meet the requirements of GDC 26.

In the DSER for Chapter 5, the staff stated that the Evolutionary Requirements Document did not specifically invoke or reference the SLCS performance requirements of the ATWS rule (10 CFR 50.62). The ATWS rule requires that the SLCS meet specific flow conditions and, for facilities granted a construction permit after July 26, 1984, have an automatic initiation feature. Also, criteria have not been specified to ensure that the insertion of boron into the vessel is distributed effectively and is thoroughly mixed.

In response, EPRI included performance requirements for boron flow and mixing in Section 4.6.2 of Revision 3 to Chapter 5. The staff concludes that these requirements will provide for adequate boron flow and mixing and, are, therefore, acceptable. This DSER open issue is closed.

4.4 Safety Classification of Containment Heat Removal System

The ALWR BWR containment heat removal system will consist of suppression pool cooling and wetwell spray (WS) and drywell spray (DS) features, which will be shared functions of the DHR system. The purpose of these systems is to prevent excessively high containment temperatures and pressures, thus maintaining containment integrity and equipment operability following a LOCA.

With regard to the design of the WS and DS, Section 4.5.2.3 of Revision 0 to Chapter 5 did not address all the acceptance criteria in SRP Section 6.2.2, "Containment Heat Removal Systems." Furthermore, the Evolutionary Requirements Document stated that the WS and DS design and equipment need not be safety grade, whereas the SRP Section 6.2.2 acceptance criteria regarding GDC 38 state that the containment heat removal system design should meet the redundancy and power source requirements of an engineered safety feature (ESF) system. In addition, SRP Section 6.2.2 calls for heat removal systems to bedesigned to Quality Group B and seismic Category I standards. In the DSER for Chapter 5, the staff requested that EPRI address these discrepancies.

In its letter dated May 22, 1991, EPRI stated that the Evolutionary Requirements Document contains provisions to reduce or eliminate suppression pool bypass leakage. EPRI revised Section 7.2.17 of Chapter 5 to require a vacuum breaker system design to prevent possible negative pressure in the drywell from becoming lower than the design negative pressure, which will preclude steam bypass. These provisions are intended to mitigate design-basis accidents (DBAs) without reliance on containment spray, thereby enabling the containment spray system to be designed to non-safety-grade standards. Therefore, EPRI concluded that the WS and DS design and equipment need not be safety grade.

EPRI proposes to use a containment heat removal system in the BWR that consists of suppression pool cooling and a spray system for the drywell and wetwell. Because the evolutionary BWR plant design does not require safety-grade fan coolers, in the absence of ESF-grade sprays, there will be no active containment atmosphere heat removal systems that would be designed to meet the acceptance criteria of SRP Section 6.2.2. The staff concludes that the spray system's function as heat removal equipment may not be of great importance, but its capability to suppress the negative aspects of suppression pool bypass represents a very important mitigative feature. All reasonable efforts should be made to improve the capability of the design to accommodate pool bypass events. In addition, the containment sprays have been demonstrated to be very effective in the scrubbing of the containment atmosphere. In view of these important features, the staff concludes that the sprays should be safety grade unless plant-specific designs can be shown to be adequate without sprays.

The staff concludes that an individual application for FDA/DC must provide justification for taking the position that the DS and WS do not need to be safety-related systems. The staff will review the specific plant designs to ensure that they comply with the SRP or that a deviation is acceptably justified. Therefore, this DSER open issue is closed. Section 7.2 of this chapter provides additional information on this issue.

4.5 Suppression Pool Bypass Leakage

In a pressure-suppression containment, steam released from the primary system following a postulated LOCA is collected in the containment drywell and directed through connecting vents to the suppression pool located in the wetwell. The steam is condensed as it enters the suppression pool. Thus, no steam enters the wetwell airspace. However, the potential exists for steam to bypass the suppression pool by leakage through the vacuum breakers or directly from leak paths in the drywell-to-suppression chamber vent pipes, the diaphragm wall seal around diaphragm penetrations, or cracks in the concrete diaphragm.

In the DSER for Chapter 5, the staff evaluated EPRI's position on steam bypass capability using Appendix A to SRP Section 6.2.1.1.C, "Pressure-Suppression Type BWR Containments," which discusses the capability of the Mark I, II, and III containment designs to tolerate steam bypass ($A/\sqrt{k}$) from the drywell to the wetwell space for small primary steam breaks. (The capability of the Mark I design is about 0.02 ft^2, the capability of the Mark II containment is approximately 0.05 ft^2, and the Mark III design has a capability of 1 ft^2.)

In a letter dated August 16, 1988, responding to the staff's request for additional information regarding steam bypass capability in the ALWR BWR containment, EPRI stated that the design criteria for the advanced BWR will minimize the potential leakage paths between the drywell and wetwell. In the DSER for Chapter 5, the staff commended the intended approach being taken in the design of the ALWR BWR to minimize the potential leakage paths between the drywell and wetwell. However, because the maximum allowable leakage area for steam bypass of the suppression pool was not provided for this design approach, and, specifically, because the design criteria did not explicitly identify greater capability to tolerate bypass leakage, the staff could not conclude that the ALWR BWR requirements were acceptable. Furthermore, because the BWR pressure suppression design is sensitive to relatively small bypass leakage areas, the staff concluded that designers of ALWRs who use that design concept should demonstrate a sufficient capability to tolerate bypass leakage.

In its letter dated December 3, 1991, EPRI responded that the ALWR BWR design has been improved to minimize the potential leakage paths from the drywell to the wetwell that bypass the suppression pool. Additionally, Section 7.2.17 of Revision 1 to Chapter 5 requires a vacuum breaker system to prevent possible negative pressure in the drywell from becoming lower than the design negative pressure, and thereby to prevent bypass. The vacuum breaker will be developed to meet safety-system requirements. The improved configuration of the ALWR BWR provides the basis for a very small drywell-to-wetwell airspace bypass leakage. Furthermore, Section 7.2.11 of Revision 1 to Chapter 5 requires that the wetwell-to-drywell barrier be constructed so as to preclude suppression pool bypass leakage. EPRI concludes that these requirements will prevent steam bypass of the suppression pool and containment pressurization resulting from insufficient condensation of steam in the suppression pool.

The staff concludes that EPRI has sufficiently improved design requirements and plant configuration criteria to preclude suppression pool bypass by minimizing potential leakage paths from the drywell to wetwell. However, the containment also should be designed to accommodate a certain amount of bypass leakage. Specific plant designers should reference SRP Sections 6.2.1.1.C and 6.2.6, "Containment Leakage Testing," when designing an ALWR BWR plant. SRP Section 6.2.1.1.C states that the system used to quench any steam bypassing the suppression pool should be designed so that the steam bypass capability for small breaks satisfies certain design-specific criteria. This DSER open issue is closed. The staff will evaluate the detailed suppression pool design during its review of an individual application for FDA/DC. Section 7.2 of this chapter provides additional information on this issue.

4.6 Suppression Pool Temperature-Monitoring System

NUREG-0783, "Suppression Pool Temperature Limits for BWR Containments," recommends that the suppression pool temperature-monitoring system meet the following general design requirements:

- Each applicant or licensee will demonstrate the adequacy of the number and distribution of pool temperature sensors to provide a reasonable measure of the bulk temperature.
- Sensors will be installed sufficiently below the minimum water level to ensure that the sensors properly monitor pool temperature.

- Pool temperature will be indicated and recorded in the control room. If the suppression pool temperature limits are based on bulk pool temperature, operating procedures or analyzing equipment should be used to minimize the actions required by the operator to determine the bulk pool temperature. Operating procedures and alarm setpoints should consider the relative accuracy of the measurement system.

- Instrument setpoints for alarms will be established so that the plant will operate within the suppression pool temperature limits.

- All sensors will be designed to seismic Category I, Quality Group B standards and be capable of being energized from onsite emergency power supplies.

In the DSER for Chapter 5, the staff stated that Section 4.5.3.4.3 of Revision 0 to Chapter 5 of the Evolutionary Requirements Document required that suppression-pool temperature sensors be located in each quadrant of the suppression pool. However, the document did not include justification or analysis to demonstrate the adequacy of the number and distribution of such temperature sensors, and it did not incorporate the general design requirements of NUREG-0783.

In Revision 1 to Chapter 5, EPRI deleted Section 4.5.3.4.3 and revised Section 7 [illegible].3 to state that the suppression pool temperature monitoring sensor groups will be located in each quadrant of the suppression pool and that the monitoring system design will meet the requirements of NUREG-0783. EPRI states that the four quadrants correspond to the four channels of the reactor protection system. However, NUREG-0783 states that the redundant temperature sensors should be located at each quencher. EPRI has not stated that its requirement for the number and distribution of temperature sensors will meet the guidance provided in NUREG-0783. Therefore, the staff will review an individual application for FDA/DC against the guidelines in NUREG-0783. This DSER open issue is closed.

5 PWR CORE DAMAGE PREVENTION REQUIREMENTS

5.1 Introduction

Section 5 of Chapter 5 of the Evolutionary Requirements Document identifies core damage prevention requirements for PWRs and states that core damage will be prevented by the following systems:

* residual heat removal (RHR) system
* emergency feedwater (EFW) system
* safety injection system (SIS)
* safety depressurization and vent system (SDVS)

In its letter dated August 16, 1988, EPRI described its probabilistic basis for providing two divisions of safety systems in PWRs. The information presented indicates that the decision was based on previous probabilistic risk assessments (PRAs), from which EPRI concluded that this approach will enable the ALWR to meet its safety goals. Since two divisions also are consistent with regulatory requirements, this approach is acceptable.

5.2 Residual Heat Removal System

In the Evolutionary Requirements Document, EPRI states that the RHR system will consist of two divisions, each with a low-pressure motor-driven pump and heat exchanger located outside the containment. The RHR system design pressure and temperature conditions are specified to be 900 psig and 400 °F. EPRI states that these design conditions will preclude the possibility of a reactor coolant system (RCS)/RHR intersystem LOCA should the RHR system be subjected to the higher RCS pressure. The two RHR pumps will have backup cross-connections to the containment spray pumps to facilitate maintenance.

Mid-Loop Operation

During certain shutdown periods, it may be necessary to perform inspection and/or maintenance operations on the steam generators and reactor coolant pumps. Toward the end of the associated cooldown, the reactor coolant inventory is reduced sufficiently to drain the steam generator channel heads and install steam generator isolation devices (nozzle dams). The RCS water level is lowered while RHR operation continues; this is termed "mid-loop" operation.

The staff concludes that in order to ensure its continued availability to perform the RHR function during mid-loop operation, design features must be incorporated in the RCS and the RHR system to prevent loss of RHR.

Section 5.2.3.1.3 of Chapter 5 of the Evolutionary Requirements Document specifies requirements relating to potential loss of decay heat removal when RCS level is lowered for maintenance during shutdown operations. EPRI has revised Section 5.2.3.1.3.2 of Chapter 5, which specifies requirements relating to shutdown level instrumentation, to require means to ensure substantial margin between the nominal level required for maintenance with the reactor fueled and the RCS level for inadvertent vortex formation.

The staff concludes that this revised set of criteria provides a set of requirements that is adequate for designing a system meeting the criteria of SECY-90-016. However, since the requirements do not require a unique design, the staff will evaluate an individual application for FDA/DC to ensure that RHR will not be lost when RCS level is lowered.

Intersystem LOCA

Revision 0 of the Evolutionary Requirements Document required that BWRs and PWRs be designed to ensure that the ultimate rupture strength (URS) of the low-pressure systems will not be exceeded even if the low-pressure system is exposed to full operating RCS pressure. In the DSER for Chapter 5, the staff concluded that EPRI's proposed resolution was acceptable, concluded that those systems that have not been designed to withstand full RCS pressure should have (1) the capability for leak testing the pressure isolation valves, (2) valve position indication that is available in the control room when isolation valve operators are deenergized, and (3) high-pressure alarms to warn control room operators when rising RCS pressure approaches the design pressure of attached low-pressure systems and both isolation valves are not closed. In addition, the staff was concerned that such a RCS could be practically designed and identified this as an open issue. Revision 3 of the Evolutionary Requirements Document included revisions of Section 2.2.14 of Chapter 3 that meet the staff's position in SECY-90-016 regarding intersystem LOCA protection. The staff concludes that these requirements are acceptable. Therefore, this DSER open issue is closed. The specific criteria that the staff will use to evaluate this issue during its review of an individual application for FDA/DC are described below. Additionally, it will be necessary for the designer to demonstrate that any reactor coolant interface system whose URS is not at least equal to full RCS pressure could not be practically designed to such a criterion.

The staff position regarding intersystem LOCA protection is that future ALWR designs should reduce the possibility of a LOCA outside the containment by designing to the extent practicable all systems and subsystems connected to the RCS to a URS at least equal to full RCS pressure.

The "extent practicable" phrase indicates a realization that all systems must eventually interface with atmospheric pressure and that for certain large tanks and heat exchangers it would be difficult or prohibitively expensive to design such systems to the URS equal to full RCS pressure.

The degree of isolation or number of barriers (e.g., three isolation valves) is not sufficient justification for using low-pressure components that can be practically designed to the URS criteria. For example, piping runs should always be designed to meet the URS criteria, as should all associated flanges, connectors, and packings (including valve stem seals, pump seals, heat exchanger tubes, valve bonnets and RCS drain and vent lines). The designer should make every effort to reduce the level of pressure challenge to all systems and subsystems connected to the RCS.

For all interfacing systems and components that do not meet all RCS URS criteria, justification is required as to why it is not practicable to reduce the pressure challenge any further. This justification must be based on engineering feasibility analysis and not solely on risk benefit tradeoffs.

For those interfaces where the impracticability of full RCS pressure capability has been acceptably justified, compensating isolation capability must be demonstrated. For example, it should be demonstrated for each interface that the degree and quality of isolation or reduced severity of the potential pressure challenges compensate for and justify the safety of the low-pressure interfacing system or component. Adequacy of pressure relief and piping of relief back to the primary containment are possible considerations. As stated in SECY-90-016, each of these high-pressure to low-pressure interfaces must also include the following protection measures: (1) the capability for leak testing of the pressure isolation valves, (2) valve position indication that is available in the control room when isolation valve operators are deenergized, and (3) high-pressure alarms to warn control room operators when rising RCS pressure approaches the design pressure of the attached low-pressure systems and both isolation valves are not closed.

The staff will evaluate compliance with these criteria during its review of an individual application for FDA/DC. This issue is also addressed in the regulatory departure analysis in Appendix B to Chapter 1 of this report.

Low-Temperature Overpressure Protection

In its letter dated March 28, 1988, regarding low-temperature overpressure protection (LTOP), EPRI stated that RHR system requirements in Chapter 5 of the Evolutionary Requirements Document will be modified to reflect requirements for LTOP and to require that the minimum end-of-life pressure relief setpoints for LTOP be considered in sizing RHR relief capacity. In its DSER for Chapter 5, the staff stated that these requirements satisfactorily addressed the its concern. In Section 5.2.3.3.2 of Revision 1 to the Evolutionary Requirements Document, EPRI added these requirements. Therefore, this DSER confirmatory issue is closed.

Shutdown Risk

The staff's concern about the safety of operations during low power or plant shutdown have been increasing. The Diablo Canyon event of April 10, 1987, highlighted a particularly sensitive condition regarding the operation of a PWR with a reduced inventory in the reactor coolant system. The staff issued Generic Letter (GL) 88-17 on October 17, 1988, based on the NRC's review of the event. The letter requested that licensees address numerous generic deficiencies to enhance operational safety during operation at reduced reactor coolant inventory. This included deficiencies in procedures, hardware, and training in the areas of (1) prevention of accident initiation, (2) early mitigation of accidents, and (3) control of radioactive material if a core-damage accident should occur. In Appendix B to Chapter 1 of the Evolutionary Requirements Document, EPRI has committed to conform to GL 88-17.

More recently, the staff investigated the loss of ac power at the Vogtle plant on March 20, 1990. The incident investigation team (IIT) report (NUREG-1410, "Loss of Vital AC Power and the Residual Heat Removal System During Mid-Loop Operations at Vogtle Unit 1 on March 20, 1990") emphasized the need for risk management of shutdown operations. These events have led the staff to conclude the following:

- Nonroutine activities and the availability of less equipment during shutdown increase the probability of complex events that challenge operators in unfamiliar ways.

- Lack of rigorous consideration of accident sequences during shutdown operations has resulted in potentially incomplete or inadequate instrumentation, emergency response procedures, and mitigative equipment.

The staff has developed a plan for evaluating safety risks during shutdown and low-power operation. The objective of this plan is to develop a thorough understanding of the manner in which activities and operations during shutdown are planned and implemented, and the root causes of past events. The staff plans to assess current regulatory requirements and, where necessary, will develop and implement appropriate regulatory actions to address the issues, including new guidance and new requirements for licensees and applicants.

Although the staff's preliminary insights indicated that most significant events to date have occurred at PWRs, the potential vulnerability of BWR plants to shutdown and low-power events cannot be ignored. Because of the safety significance of events during shutdown and low-power conditions, the staff has determined that proper consideration of such events will be required before FDA is issued for evolutionary ALWR designs. To demonstrate adequate treatment of shutdown risk for ALWRs, the staff will require

- adequate vendor assessment of shutdown and low-power risk, identifying design-specific vulnerabilities and weaknesses

- documentation showing consideration and incorporation of design features that minimize shutdown and low-power risk vulnerabilities

In letters dated December 2 and 16, 1991, EPRI responded to a set of staff questions related to shutdown and low-power operations; EPRI indicated that many of the concerns identified in NUREG-1410 are the plant owner's responsibility because these concerns are related to operation, maintenance, and refueling plans; procedures; and risk management; and that a review of NUREG-1410 is expected to be included in the review of plant experiences required of each ALWR plant designer. The staff concludes that EPRI could provide clearer guidance to address these concerns, but also concludes that EPRI's response to this issue is adequate at this time. However, this issue is being reviewed by the staff, as discussed in NUREG-1449, "Shutdown and Low-Power Operation at Commercial Nuclear Power Plants in the United States" (draft report for comment), February 1992. After reviewing NUREG-1449, EPRI should consider including some of its guidance in the Evolutionary Requirements Document. The staff will evaluate this matter during its review of an individual application for FDA/DC to ensure that the design satisfies the requirements subsequently developed from the staff's evaluation of shutdown risk.

5.3 Emergency Feedwater System

Section 5.3.1.2 of Chapter 5 of the Evolutionary Requirements Document describes the ALWR emergency feedwater system (EFWS) as a dedicated safety-related system that will have no normal operational functions. The EFWS will provide feedwater to the steam generators following such transients or accidents as reactor trip, loss of main feedwater, steam or feedwater line breaks, or steam generator tube ruptures, and anytime the main and startup feedwater systems are not available. The ALWR EFWS will consist of two independent, identical subsystems. Each subsystem will comprise one motor-driven and one turbine-driven feedwater pump, an emergency feedwater storage tank (EFWST), and associated piping, valves, and instrumentation and controls. Each subsystem will be powered by one of two separate Safety Class 1E electrical power sources. The ALWR EFWS will be designed so that any two pumps for four steam generator plants, and any one pump for two steam generator plants, will be capable of satisfying the flow requirements for design-basis conditions plus any additional flow required for minimum flow protection for the pump. Any single pump must be capable of satisfying the minimum flow requirement for best-estimate decay heat removal evaluations. Each of the safety-related EFWSTs will contain enough condensate-quality water to achieve safe cold shutdown, based on

- a main feedline break without isolation of EFW flow to the affected steam generator for 30 minutes
- refill of the intact steam generators
- 8 hours of operation at hot standby conditions
- subsequent cooldown of the reactor coolant system within 6 hours to conditions that permit operation of the RHR system
- continuous operation of one reactor coolant pump

Section 5.3.3.1.4 of Chapter 5 states that a cross-connect line must be provided between the two EFWSTs to allow the supply of feedwater to all EFW pumps. In addition, a backup supply of condensate-quality feedwater will be provided to the EFWSTs and the transfer of water to the EFWSTs will be possible under station blackout conditions. However, this backup supply need not be safety related. The Evolutionary Requirements Document also specifies interfacing requirements for the alternative water supply to the EFWS.

Section 5.3.3.1.8 of Chapter 5 states that the EFWS must be equipped with four cavitating venturi flow meters (two for two steam generator plants), one on each discharge line to the steam generator. In the event of steamline or feedwater line rupture, these cavitating venturi flow meters will choke the EFWS flow to the steam generators to prevent pump damage due to runout and to prevent excessive rates of cooldown of the reactor coolant system. If the break is inside the containment, the cavitating venturi flow meters will limit the effect of EFWS flow on the mass and energy released to the containment.

In addition, the Evolutionary Requirements Document states that the EFWS must be provided with a means to detect potential EFWS pump steam binding as a result of steam and hot water leakage through check valves in the pump discharge lines. This will consist of temperature monitoring of the portion of discharge piping upstream of the check valves, with indication and alarm in the control room. Appropriate vents and drains will be provided for removing steam in the event steam is detected. The Evolutionary Requirements Document also states that the EFWS must be provided with means to permit periodic surveillance testing of EFW pumps and valves and functional testing of the integrated operation of the system. Flow to the steam generators is to be prevented during testing to avoid unnecessary thermal transients and inputs of oxygenated water to the steam generators. Appropriate access will be provided to test power-operated valves. Means must be provided to test the pumps at the design flow with the reactor in operation.

Section 5.3.2.5.1 of Chapter 5 states that emergency feedwater supplied to steam generators will be of the same or better quality as secondary system makeup water, except that the requirement on oxygen can be excluded. This is consistent with the SRP and is acceptable.

Section 5.3.2.4 of Revision 0 of Chapter 5 of the Evolutionary Requirements Document referenced Section 4.2.3-4 of Chapter 3, which specified automatic or manual options for initiation of emergency feedwater flow. In the DSER for Chapter 5, the staff stated that both automatic and manual initiation should be necessary. In a letter dated August 16, 1988, EPRI committed to modify Section 4.2.3-4 of Chapter 3. This was identified as a confirmatory issue in the DSER. In Revision 1 of the Evolutionary Requirements Document, EPRI made the revision to Chapter 3 to specify automatic and manual initiation of EFW flow. The staff concludes that the revised statements meet 10 CFR 50.34(f)(2)(xii) and are acceptable. Therefore, this DSER confirmatory issue is closed.

The staff concludes that the EFWS design requirements are consistent with the criteria in SRP Section 10.4.9, "Auxiliary Feedwater Systems," and are, therefore, acceptable.

5.4 Safety Injection System

Section 5.4 of Chapter 5 of the Evolutionary Requirements Document describes a safety injection system (SIS) that will consist of two high-pressure divisions, each having two trains (total of four motor-driven 50-percent pumps). Low-head pumps and series (piggyback) pump alignment will not be used in the ALWR design. The SIS pumps should be located outside the containment, should take suction from a common in-containment refueling water storage tank (IRWST), and should inject directly into the vessel by way of independent piping connections to the reactor vessel. Discharge connections to the hot legs should also be provided. Each division will have sufficient capacity to satisfy design-basis-accident (DBA) LOCA requirements in accordance with regulatory requirements, and small-break LOCA investment protection requirements [i.e., no fuel damage for 6-inch (12-inch target) break]. The number of SIS accumulators is not specified, and will be "minimized." Injection pressure will be selected by the designer and will be high enough to permit feed-and-bleed cooling. The IRWST will eliminate the need to switch SIS suction to a containment sump for continued supply of injection water. This feature will greatly reduce complexity and increase system reliability. The IRWST will also serve as an RCS relief discharge tank. The staff concludes these features are acceptable.

In Revision 3 of Chapter 5, EPRI requires that the safety depressurization and vent system be capable of reducing reactor coolant system pressure to 250 psig or less before reactor vessel melt-through, as a means to preclude containment challenges through direct containment heating (DCH). The staff concludes that this is an acceptable design objective. However, the designer should justify that the automatic depressurization system will depressurize low enough to preclude DCH. The designer should also demonstrate that the depressurization system is adequate to provide sufficient capacity to handle primary feed-and-bleed operations during a total loss-of-feedwater event and to prevent creep rupture of steam generator tubes from a postulated high- pressure core-damage event. The staff will evaluate this matter during its review of an individual application for FDA/DC to ensure the designer demonstrates that SIS injection pressure is sufficient to permit feed-and-bleed operation. This DSER open issue is closed.

5.5 Safety Depressurization and Vent System

Section 5.5 of Chapter 5 of the Evolutionary Requirements Document states that a safety depressurization and vent system will be provided for the ALWR that will consist of a single passive piping system containing two active, safety-grade valve trains. Four valves will be installed in two parallel flow branches, in piping from the pressurizer to the IRWST, to provide single-active-failure vent and depressurization capability for natural circulation cooldown, steam generator tube rupture, and feed-and-bleed conditions. One valve assembly flow path (train) is adequate for feed-and-bleed cooling in the event of a total loss of feedwater if feed and bleed is established immediately. Both paths are required if feed and bleed is delayed for 1 hour after safety valve lift. See Section 6.6.5 of this chapter for a discussion of the open item concerning the SDVS.

6 MITIGATION REQUIREMENTS

6.1 Introduction

Section 6 of Chapter 5 of the Evolutionary Requirements Document specifies mitigation requirements applicable to both BWRs and PWRs. Mitigation will rely on two functions: (1) the containment integrity function and (2) the fission product control function. The containment is intended to serve as a barrier to the uncontrolled release of radioactivity in the event of an accident.

6.2 Containment Isolation System Design

The function of the containment isolation system is to permit the normal and emergency passage of fluids through the containment boundary while preserving the capability of the boundary to prevent or limit the escape of fission products that may result from postulated accidents. The containment isolation system includes the portions of all fluid systems penetrating the containment that perform the isolation function. EPRI states that isolation provisions in lines penetrating the containment boundary will be in accordance with American National Standards Institute/American Nuclear Society (ANSI/ANS) 56.2-1984, "Containment Isolation Provisions for Fluid Systems After a LOCA," and Regulatory Guide (RG) 1.141, "Containment Isolation Provisions for Fluid Systems." However, ANSI/ANS 56.2-1984 has not been approved by the staff for the design of containment isolation systems. The staff has reviewed the ALWR requirements for containment isolation systems against the guidelines of SRP Section 6.2.4, "Containment Isolation System," and ANSI/ANS 56.2-1976, which has been approved by the staff.

General Design Criteria (GDC) 55 and 56 of Appendix A to 10 CFR Part 50 require that each line that penetrates the containment and is part of the reactor coolant pressure boundary or is connected directly to the containment atmosphere have one isolation valve inside and one isolation valve outside the containment, unless it can be demonstrated that the design is acceptable on some "other defined basis." Each valve must be automatic or locked closed. In satisfying GDC 55 and 56, Section 3.6 and Appendices A and B of ANSI/ANS 56.2-1976 provide guidelines that the staff has found acceptable.

In Section 6.2.2.1.2 of Revision 0 of the Evolutionary Requirements Document, EPRI stated that remote manual valves, instead of automatic valves, may be used for lines that are not part of engineered safety systems, but are classified as essential on another basis, such as being required to maintain the integrity of in-containment components, for example, cooling water lines to reactor coolant pumps. In its DSER for Chapter 5, the staff stated that this position for containment isolation was inconsistent with the guidance in Section 3.6.3, "Remote Manual Valves," of ANSI/ANS 56.2-1976 and that EPRI should provide acceptable justification for this proposed alternative.

In Revision 1 of Chapter 5, EPRI revised Section 6.2.2.1.2 to state, in part, that justification will be provided for each use of a remote manual valve instead of an automatic valve. The justification will include an evaluation identifying the indications and timing under which isolation must be initiated for inclusion in off-normal operating procedures.

In Item II.E.4.2 of NUREG-0737 ("Clarification of TMI Action Plan Requirements") and NUREG-0718 ("Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License"), the staff states that systems penetrating the containment will be classified as either essential or nonessential. RG 1.141 provides guidance on the classification of system lines. Generally, essential systems are lines in ESFs or ESF-related systems needed for safe shutdown of the plant. These essential lines may include remote manual valves, but provisions should be made to detect possible leakage from these lines outside the containment. EPRI has stated that the use of remote manual valves for such service must be justified case by case. The staff will review an individual application for FDA/DC against SRP Section 6.2.4. It concludes that EPRI's position is acceptable, and this DSER open issue is closed.

In Section 6.2.2.1.2 of Revision 0 to Chapter 5 of the Evolutionary Requirements Document, EPRI also stated that if a single isolation valve is employed for an ESF line (e.g., lines connected to the suppression pool in a BWR and lines connected to the in-containment refueling water storage tank (IRWST) in a PWR), the valve need not be enclosed in a leak-tight enclosure if the line inside the containment is submerged under water at all times following a LOCA. Note 56.1 in Appendix A of ANSI/ANS 56.2-1976 states that each line connecting directly to the suppression pool should be provided with a single remote manual or automatic isolation valve. These valves are attached to lines that are an extension of the containment and are enclosed in a pump room adjacent to the containment which has provisions for environmental control of any fluid leakage. The lines from the suppression pool would always be submerged, so no containment atmosphere can impinge on the valves. Should a leak develop outside the containment, the fluid would be contained in the controlled-leakage pump room. The configuration of the connection of the lines to the suppression pool ensures that the connections are always submerged and prevents the escape of containment atmosphere. In addition, the systems to which the lines from the suppression pool connect to outside the containment must be closed systems (outside the containment) to meet the appropriate requirements of closed systems described in ANSI/ANS 56.2-1976. In the DSER for Chapter 5, the staff stated that EPRI did not indicate that all of these criteria will be met for the IRWST connections.

In Revision 1 of Chapter 5, EPRI revised Section 6.2.2.1.2 to state that the criteria for using a single valve for isolating the lines connecting to the IRWST will be the same as those for the suppression pool of a BWR provided in Note 56.1 of Appendix A to ANSI/ANS 56.2-1984. In the rationale, EPRI states that lines connected to the suppression pool in BWRs have typically not been required to have the isolation valve and a line connected to the containment enclosed in a leak-tight housing because the line would remain filled with water following a LOCA, minimizing the leakage of containment gas. PWR recirculation lines connected to the IRWST will also remain filled with water following a LOCA, minimizing the leakage of containment air. The staff concludes that EPRI has addressed the containment isolation provisions for the lines connected to the IRWST and that EPRI's position is acceptable. Therefore, this DSER open issue is closed.

In its letter dated August 16, 1988, EPRI described its position regarding seismic design for closed systems and Type C testing of valves in closed systems performed in accordance with Appendix J to 10 CFR Part 50. EPRI stated that seismic design will be used where practical to qualify closed systems outside the containment as "extensions of containment" in order to eliminate the need for Type C testing of the valves. In the DSER for Chapter 5, the staff stated that a closed system outside the containment that meets the criteria of Section 3.6 of ANSI/ANS 56.2-1976 can be considered a second containment isolation barrier, thereby eliminating the need for a second containment isolation valve at each penetration. However, each barrier (i.e., the single isolation valve at each penetration, and the closed piping system outside the containment) is subject to leak rate testing.

In Section 6.2.2.2 of Revision 1 of Chapter 5, EPRI revised the conditions under which Type C testing may be avoided, including compliance to Section 6.3.2.2 for water-sealed lines. Section 6.2.2.2 states that Type C testing may be avoided for valves in the water-sealed lines that terminate in closed systems outside the containment, if the systems are designed to qualify as extensions of the containment in accordance with Section 3.6 of ANSI/ANS 56.2.

The staff's position is that a closed system outside the containment does not meet the requirements of GDC 57. However, SRP Section 6.2.6, "Containment Leakage Testing," allows a closed system outside the containment to have a single isolation valve outside the containment provided the piping outside the containment is designed as seismic Category I and Safety Class II. The valve should be Type C tested and the piping outside the containment should be leakage rate tested, unless the pipe is pressurized at all times and meets certain regulations. For water-sealed valves, Type C testing with water is acceptable and the test results need not be added to the Type C test total. Therefore, EPRI's position on eliminating Type C testing for the water-sealed lines outside the containment is unacceptable. The staff will review individual applications for FDA/DC to the criteria in SRP Section 6.2.6. This DSER open issue is closed.

In Section 6.2.2.2 of Chapter 5, EPRI states that Type C testing is not required for PWR main steam, feedwater, emergency feedwater, or steam generator blowdown isolation valves. These isolation valves are associated with secondary systems. The closed system inside the containment precludes containment atmosphere from reaching the associated isolation valves; therefore, the valves will not be relied on to limit containment leakage. The staff finds this criterion acceptable.

In Section 6.2.2.3.1 of Chapter 5, EPRI states that isolation valve closure times will be in accordance with ANSI/ANS 56.2-1984 for standard commercial valve operators. Since this requirement is essentially the same as that of ANSI/ANS 56.2-1976, which has been approved by the staff, it is acceptable.

6.3 Containment Leakage Rate Testing

Section 6.2.2.2 of Chapter 5 of the Evolutionary Requirements Document states that isolation provisions should be designed to minimize the number of isolation valves that are subject to Type C tests (in accordance with Appendix J to 10 CFR Part 50), and the number of penetrations requiring isolation valves should be minimized by system design. Included are those penetrations that have resilient seals and expansion bellows (e.g., personnel air locks, equipment hatch, fuel transfer tube, and electrical penetrations). Section 6.3.2.1 of Chapter 5 requires that containment leak rate testing be performed in accordance with regulatory requirements and the test methods be in accordance with ANSI/ANS-56.8, "Containment System Leakage Testing Requirements," in lieu of ANSI N45.4-1972, "Leakage Rate Testing of Containment Structures for Nuclear Reactors." In Section 6.3.2.2, EPRI [illegible] that Appendix J requirements will take precedence in the event of [illegible] conflict between Appendix J and ANSI/ANS 56.8, except for the exceptions discussed below.

6.3.1 Containment Integrated Leak Rate Test

Paragraph III.A.3 of Appendix J to 10 CFR Part 50 requires that

> All Type A tests shall be conducted in accordance with the provisions of the American National Standard N45.4-1972, "Leakage Rate Testing of Containment Structures for Nuclear Reactors," March 16, 1972. In addition to the Total Time and Point-to-Point methods described in that standard, the Mass Point Method, when used with a test duration of at least 24 hours, is an acceptable method to use to calculate leakage rates. A typical description of the Mass Point Method can be found in the American National Standard ANSI/ANS 56.8-1987, "Containment System Leakage Testing Requirements," January 20, 1987.

Therefore, using the Mass Point Method for ALWR designs is acceptable. However, the staff's acceptance of ANSI/ANS 56.8-1987 extends only to its description of the Mass Point Method, not to the standard in its entirety.

The staff has proposed a general revision of Appendix J (see "J-FRN (Post-ACRS)," dated September 26, 1991, and released to the Public Document Room on January 10, 1992) and has proposed to issue a related new regulatory guide (MS 021-5, dated April 3, 1991, and released to the Public Document Room on April 9, 1991). The proposed regulatory guide endorses ANSI/ANS 56.8-1987, with several significant exceptions. The staff will review individual FDA/DC applications to the criteria in the proposed regulatory guide.

In Section 6.3.2.2 of Chapter 5, EPRI states that integrated leak rate tests (ILRTs) can proceed to completion should a leak occur during testing, provided the leak can be isolated, subsequent repairs are performed, and local "as found" minus "as left" leakage rate test results when added to the Type A result demonstrate that the ILRT acceptance criteria are met. The proposed revision to Appendix J states that isolation, repair, or adjustment of a leakage barrier that may affect the leakage rate through that barrier is permitted before or during the Type A test provided

- all potential leakage paths of the isolated, repaired, or adjusted leakage barrier are locally leak testable.

- the local leakage rates are measured before and after the repair or adjustment or any other action taken that will affect the leakage rates, and are reported.

- all changes in leakage rates resulting from isolation, repair, or adjustment of leakage barriers subject to Type B or Type C testing are determined using the minimum pathway leakage rate method. When performed during an outage in which a Type A test is performed, these leakage rates are added to the Type A test results to obtain the "as found" and "as left" containment leakage rates.

The method for completing Type A testing proposed by EPRI is a plant optimization issue that deviates from the current requirements of Appendix J. However, the proposed method conforms with the current staff position as delineated in the NRC-proposed rule. Therefore, justification for the proposed rule change can be submitted in support of an application for design certification. The staff will evaluate this matter during its review of an individual FDA/DC application. This issue is closed.

6.3.2 Type B Air-Lock Tests

In Section 6.3.2.2 of Revision 0 to Chapter 5 of the Evolutionary Requirements Document, EPRI stated that air locks that are not used during a 6-month period may be tested at containment design pressure after the next usage rather than at 6 months, as required by Appendix J to 10 CFR Part 50. In its DSER for Chapter 5, the staff stated that supporting data (e.g., long-term deterioration of seals) from operating experience or from experiments with appropriate analyses have not been provided to justify this deviation from the Appendix J requirement. The staff was unable to conclude that the proposed change to the air-lock Type B test interval was acceptable. However, the staff has reevaluated this issue as discussed below.

The proposed revision to Appendix J of 10 CFR Part 50 states:

> Air locks must be tested prior to the preoperational Type A test and at least once each 6-month interval thereafter at an internal pressure not less than P_{ac}. Alternatively, if there have been no air-lock openings within 6 months of the last successful test at P_{ac}, this interval may be extended to the next refueling outage or air lock opening, whichever comes first (but in no case may the interval exceed 30 months). Under this alternative, reduced pressure tests must continue to be performed on the air lock or its door seals at 6-month intervals. Opening of the air lock for the purpose of removing air lock testing equipment following an air lock test does not require further testing of the air lock. An air lock also will not be considered as "opened" for the purpose of this requirement if it has not been opened since its latest leakage rate test, and if the outer door is being opened for no other reason than to enable testing of the air lock's inner door seals. In this case, subsequent testing of the outer door's seals is sufficient.

The air-lock test interval proposed by EPRI is a plant optimization issue that deviates from the current requirements of Appendix J. However, the proposed test interval conforms with the current staff position as delineated in the NRC-proposed rule. Therefore, justification for the proposed rule change can be submitted in support of an application for design certification. The staff will evaluate this matter during its review of an individual application for FDA/DC. This DSER open issue is closed.

6.3.3 Type C Containment Local Leak Rate Tests

In Section 6.3.2.2 of Revision 1 to Chapter 5 of the Evolutionary Requirements Document, EPRI stated that those valves that are in lines designed to be filled with a liquid for at least 30 days subsequent to an accident may be leakage rate tested with a liquid. Liquid leakage is not converted to equivalent air leakage nor is it added to the Type C testing total, but is reported as liquid leakage. In its DSER for Chapter 5, the staff stated that this was acceptable, provided

- such valves have been demonstrated to have fluid leakage rates that do not exceed their design leakage rates

- the installed fluid inventory in the isolation valve's seal-water system is sufficient to ensure the sealing function for at least 30 days at a pressure of 1.10 P_a (calculated peak pressure)

EPRI revised Section 6.3.2.2 of Revision 1 to Chapter 5 to conform with the staff's guidelines. Therefore, the staff concludes that leakage rate testing for the water-sealed valves as proposed by EPRI is acceptable and that this DSER open issue is closed. However, in the DSER for Chapter 5, the staff recommended that EPRI change the word "liquid" to "water" in Section 6.3.2.2 for clarification. Additionally, it should be noted that "design leakage rate" means that leakage rate, to be stated in individual plant technical specifications, which will ensure that the seal-water inventory will not be exhausted for at least 30 days. Also, a single active failure must be considered when assessing the sealing function. Pending incorporation of this change, the staff will evaluate this matter during its review of an individual application for FDA/DC or combined license. Therefore, this DSER confirmatory issue is closed.

Appendix J to 10 CFR Part 50 requires that Type C tests be performed during each reactor shutdown for refueling, but in no case at intervals greater than 2 years. The Evolutionary Requirements Document requires that the maximum interval between Type C tests be 30 months rather than the 24 months currently required by Appendix J. This is based on the expectation that there would not be any significant increase in the average leakage rate from all valves subjected to Type C testing if the test interval were increased to 30 months. In Section C.1 of Appendix C of Revision 0 to Chapter 5, EPRI provided the rationale for this proposal, which is considered an optimization issue in terms of risk, occupational exposure, and cost. (Appendix C has been deleted from Chapter 5 and those requirements relocated to Section 2 of Appendix B to Chapter 1.) Additionally, the staff noted that the Evolutionary Requirements Document proposes administrative controls and no continuous or periodic short-duration checks of containment integrity. In its DSER for Chapter 5, the staff stated that supporting data (e.g., long-term deterioration of seals and valve seats) from operating experience or experiments with appropriate analyses had not been provided to justify this deviation from the Appendix J requirement. The staff was unable to conclude that the proposed change to the Type C test interval was acceptable.

However, this issue is consistent with the staff's current position as delineated in the proposed revision to Appendix J, which will change the Type C test interval from 24 months to 30 months. The proposed rule is awaiting the approval of the Commission. The staff concludes that the justification for the proposed rule change can be submitted in support of an application for design certification. The staff will evaluate this matter during its review of an individual application for FDA/DC. This DSER open issue is closed. This issue is also discussed in the regulatory departure analysis of Appendix B to Chapter 1 of this report.

6.4 Fission Product Leakage Control

The Evolutionary Requirements Document states that a function of the fission product leakage control systems (FPLCSs) and structures is to limit the potential release of radioactive materials that would result from postulated accidents so that the resulting offsite doses are less than the guideline values of 10 CFR Part 100 and the control room personnel exposure limits are less than the limits of GDC 19. The detailed design of the system and the evaluation of the radiological consequences from postulated accidents are outside the scope of the Evolutionary Requirements Document because several of the key values used in the analytical model are site dependent (e.g., containment design, containment isolation system, building and equipment arrangement, and meteorological factors). However, the Evolutionary Requirements Document does specify some system interface requirements. For example, Section 6.4.2.1 of Chapter 5 states that the FPLCS function will include collecting and processing of the fission products released through the identified and unidentified leakage paths during design-basis events. In addition, the Evolutionary Requirements Document states that the FPLCS boundary and/or those internal components that house high-energy lines, or through which they pass, should be designed to accommodate the failure of such lines. Leak-before-break technology will be used in the analyses. The staff's evaluation of EPRI's leak-before-break approach is given in Section 4.5.5 of Chapter 1 of this report.

The Evolutionary Requirements Document originally stated that the analysis of the pressure and temperature response of the FPLCS boundary to a LOCA and the radiological consequences from postulated accidents, including fuel-handling accidents, should be based on realistic assumptions. In its DSER for Chapter 5, the staff stated that the Evolutionary Requirements Document had not provided the detailed justifications for the use of best-estimate instead of the conservative analyses provided by the guidelines of SRP Section 6.5.3, "Fission Product Control Systems and Structures." EPRI has revised Section 6.4.2.3 of Revision 1 of Chapter 5 to state that the analysis will be based on regulatory methods rather than realistic methods. Therefore, the Evolutionary Requirements Document provides appropriate interface requirements consistent with SRP Section 6.5.3. This DSER open issue is closed.

6.5 Combustible Gas Control

The staff evaluated the combustible gas control features proposed in the Evolutionary Requirements Document. These items are also addressed in the regulatory departure analysis of Appendix B to Chapter 1 of this report.

6.5.1 Metal-Water Reaction and Hydrogen Concentration

In Revision 0 to the Evolutionary Requirements Document, EPRI specified that (1) the hydrogen control system must be capable of handling an amount of hydrogen equivalent to that generated from oxidation of 75 percent of the fuel cladding surrounding the active fuel and (2) the hydrogen concentration inside the containment must be controlled to ensure that the uniformly distributed concentration does not exceed 13 percent under dry conditions or that the atmosphere is rendered noncombustible. By letter dated September 15, 1988, EPRI provided further justification for this approach.

In the DSER for Chapter 5, the staff stated that advanced designs should, at a minimum, meet the requirements in 10 CFR 50.34(f). Although this section of the regulations was originally written for a select group of plants whose construction permits were pending as of February 1982, 10 CFR Part 52 established these requirements as a minimum standard for future plants.

The requirements of 10 CFR 50.34(f) specify that a hydrogen control system that can safely accommodate hydrogen generated by the equivalent of a 100-percent fuel-cladding metal-water reaction must be provided in the design of nuclear plants for which the regulation is applicable. Additionally, the regulation specifies that the hydrogen control system must be designed to ensure that uniformly distributed hydrogen concentrations in the containment do not exceed 10 percent, rather than the 13 percent specified by the Evolutionary Requirements Document, or that the postaccident atmosphere will not support hydrogen combustion.

Aside from the issue of regulatory compliance and applicability, the staff concluded in the DSER for Chapter 5 that compliance with the criteria of 10 CFR 50.34(f) remains appropriate for combustible gas control design in ALWRs. Research (discussed in NUREG/CR-4551, "Evaluation of Severe Accident Risks: Quantification of Input Parameters") indicates that in-vessel hydrogen generation associated with core damage accidents may range from approximately 40 to 95 percent active cladding oxidation equivalent. The amount of cladding oxidation is dependent on a variety of parameters related to sequence progression: reactor coolant system pressure, reflood timing and flow rates, and core-melt progression phenomena. Thus, a 75-percent-equivalent cladding reaction continues to be viewed as a reasonable design basis for hydrogen generation for severe accidents in which the reactor pressure vessel (RPV) remains intact. However, in the DSER for Chapter 5, the staff stated that ALWRs should provide protection for hydrogen generation resulting from a wider spectrum of accidents, that is, full core-melt accidents with RPV failure. In that context, it is also necessary to consider ex-vessel hydrogen generation as a result of core debris reacting with available water or core-concrete interactions. Calculations using the CORCON models indicate that if the core debris is cooled in relatively rapid fashion (1-2 hours), then additional hydrogen generation will be less than that equivalent to a 25-percent cladding oxidation reaction. This relatively limited ex-vessel reaction is conditional on the existence of a coolable debris bed and the availability of sufficient water. Because extensive core-concrete interaction occurs if the cavity does not flood, more hydrogen generation should be considered. Considering the effects discussed above, the staff concludes that an equivalent 100-percent cladding oxidation reaction is an appropriate deterministic design criterion and a reasonable surrogate for the combination of both in-vessel and ex-vessel hydrogen generation.

Therefore, the staff concluded that EPRI had not provided sufficient justification for an exemption to the rule nor had it provided a sufficient basis for not including mitigation capability in the ALWR design criteria for a potentially threatening early containment loading phenomenon. In its staff requirements memorandum (SRM) dated June 26, 1990, the Commission stated that the requirements of 10 CFR 50.34(f)(2)(ix) should remain unchanged for evolutionary LWRs.

Sections 2.4.1.6 and 2.4.1.7 of Revision 1 to Chapter 5 stated that the plant designer should ensure that a detonable mixture will not exist for an amount of hydrogen equivalent to that generated by oxidation of 75 percent of the fuel cladding surrounding the active fuel, and that the uniformly distributed gas concentration in the containment will not exceed 13 percent under dry conditions. Section 6.5 of Chapter 5 adds additional requirements using this criterion for combustible gas control. In its December 6, 1991, letter, EPRI stated that it will modify the Evolutionary Requirements Document to fully comply with the staff's position of 100-percent active fuel cladding and a maximum containment concentration of 10 percent. The staff's position is that the plant-specific designs must comply with the provisions in 10 CFR 50.34(f) for combustible gas control as stated in SECY-90-016.

EPRI has indicated its intent to comply with the staff position. The staff will review individual applications for FDA/DC against the criteria in 10 CFR 50.34(f) and SECY-90-016. Therefore, this DSER open issue is closed. Additional information concerning the staff's position regarding acceptable implementation of these requirements is given in Appendix B to Chapter 1 and Section 2.3 of Chapter 5 of this report.

6.5.2 Radiolytic Hydrogen Generation

In its letter dated April 4, 1988, the staff questioned EPRI's proposed provisions for hydrogen control in inerted plants. In its response dated August 16, 1988, EPRI replied that specific analyses had not been performed for the ALWR design but that on the basis of the findings in NEDO-22155, "Generation and Mitigation of Combustible Gas Mixtures in Inerted Mark I Containments," recombiners are expected to be unnecessary for the BWR ALWR because of inerted operation. EPRI also stated that Section 6.5.2.6 of Chapter 5 of the Evolutionary Requirements Document required the plant designer to define a suitable scheme of postaccident hydrogen control. In its DSER for Chapter 5, the staff noted that NEDO-22155 only applies to inerted Mark I containments and thus may not be applicable to the ALWR design.

In its DSER for Chapter 5, the staff stated that Section 6.5.2.6 of Chapter 5 did not specifically define recombiner requirements or alternative hydrogen control provisions for ALWR designs. Compliance with SRP Section 6.2.5, "Combustible Gas Control in Containment," and regulatory requirements could not be evaluated. The staff concluded that the Evolutionary Requirements Document should be expanded to identify the means for accommodating radiolytically generated hydrogen and oxygen or EPRI should clarify its position that the issue will be left to the designer.

In Section 6.5 of Revision 1 to Chapter 5, EPRI assumed that the amount of hydrogen generated was equivalent to 75 percent of the fuel cladding surface and a uniformly distributed hydrogen concentration was not to exceed 13 percent. As discussed above, these criteria do not agree with either 10 CFR 50.34(f) or SECY-90-016.

In its December 6, 1991, letter, EPRI stated that it will modify the Evolutionary Requirements Document to fully comply with the staff position on 100-percent active fuel cladding and a maximum containment concentration of 10 percent.

The staff concludes that EPRI's intent to comply with 10 CFR 50.34(f) for combustible gas control will satisfy the staff's position. The staff will review an individual application for FDA/DC against the criteria in 10 CFR 50.34(f) and SECY-90-016 to ensure compliance with the staff's position. This DSER open issue is closed.

6.5.3 Inerting/Igniters

The Evolutionary Requirements Document provides the option to use inerting as a means of combustible gas control. Inerting is an acceptable means of combustible gas control. If the plant designer chooses to inert the containment, the designer must ascertain that during postaccident conditions the amount of oxygen generated by radiolysis or introduced from other sources will not produce oxygen concentrations that would deinert the containment atmosphere so that deflagration or even detonation of the accumulated hydrogen could occur. The amount of oxygen generated from these sources is determined by plant design, and plant-specific analyses will be required during the design phase. The staff will evaluate the plant-specific analyses as part of its review of an application for FDA/DC to ensure compliance with this position.

In its DSER for Chapter 5, the staff stated that if a deliberate ignition system (i.e., igniters) is selected for combustible gas control, safety-related equipment will be required to be capable of surviving the potential deflagrations to which it might be exposed. EPRI did not provide guidance regarding the timing of igniter activation in the event of an accident. In the DSER, the staff also stated that such a deliberate ignition system should be activated early in the accident sequence, but no later than before local or global detonable concentrations develop (either directly or through deinertion of the containment by containment spray and/or steam). The staff concluded that the Evolutionary Requirements Document should provide appropriate guidance regarding the timing of igniter activation in the event of an accident.

In Section 6.5.3.1.6 of Revision 1 to Chapter 5, EPRI states that the designer will define criteria (including timing) for manual initiation and shutdown of the hydrogen igniter system. Initiation will precede possible hydrogen generation and shutdown should follow verification of a safe, stable plant condition. This position appears to be consistent with the position in SECY-90-016 that a deliberate system should be provided that will control the combustible gas. However, the Evolutionary Requirements Document assumes that hydrogen is generated equivalent to 75 percent of the fuel cladding surface and a distributed hydrogen concentration not to exceed 13 percent, which does not agree with 10 CFR 50.34(f) or SECY-90-016. Therefore, the supporting analyses necessary to show the response of the igniter system to a credible event would be based on criteria other than that found acceptable by the staff.

EPRI's position to provide criteria for initiation of the igniters on a design-specific basis is acceptable to the staff. With respect to the design criteria to be used for the igniters and supporting analyses, the staff will review an individual application for FDA/DC against the criteria in 10 CFR 50.34(f) and SECY-90-016 and the timing of igniter actuation when determined by the plant designer. This DSER open issue is closed.

6.5.4 Severe-Accident Equipment Requirements

EPRI states that transmitters and other instrument sensors required for severe accidents will be located outside the containment or will be able to operate in the severe-accident environment. Further, equipment useful for mitigating severe accidents will be designed to perform its identified function during severe accidents. Table B.1-1 in Appendix B to Chapter 1 of the Evolutionary Requirements Document requires compliance with 10 CFR 50.34(f)(2)(xvii), which addresses the requirements for placement and operation of containment high-range area radiation monitors (TMI Action Plan Item II.F.1).

The staff concludes that the design criteria for this equipment meet the Commission's regulations, and are, therefore, acceptable.

6.6 Severe-Accident Requirements

On December 13, 1988, the staff sponsored a meeting with representatives of the nuclear power industry and the general public to discuss the staff's and industry's approach to resolving severe-accident issues for ALWRs. The staff presented alternative approaches that were being considered to address various severe-accident challenges. Since the December 1988 meeting, the staff has continued to develop its positions on severe-accident criteria. The staff reviewed EPRI's approach to resolving these issues (as described in Section 6.6 of Chapter 5 of the Evolutionary Requirements Document) for consistency with current staff positions. The staff's evaluation of those features proposed to address severe-accident concerns follows. These features, and the staff's evaluation of them, are applicable to both PWRs and BWRs.

6.6.1 Containment Margin

To ensure the integrity of the containment structure, in its letter dated April 24, 1991, the staff asked EPRI to consider load combinations associated with LOCA (i.e., LOCA plus hydrogen burn and safe-shutdown earthquake (SSE) plus LOCA). In its letter dated July 2, 1991, EPRI stated that LOCA plus hydrogen burn and SSE plus LOCA are discussed in Section 6.6.2.2 of Chapter 5 and Section 4.6.1.1 of Chapter 1, respectively. The staff concludes that EPRI's response is acceptable.

Section 6.6 of Chapter 5 presents design requirements associated with severe accidents. In its letter dated July 2, 1991, EPRI stated that Section 6.6.2.2 of Chapter 5 gives stress and buckling criteria for the containment under a severe-accident loading condition described in Section 2.4.1.7 of Chapter 5. This response deviates from the guidelines in SECY-90-016. Currently, there is no specific deterministic regulatory requirement on structures, systems, and components (SSCs) for severe-accident conditions except that SRP Sections 3.8.1, "Concrete Containment," and 3.8.2, "Steel Containment," require that a containment ultimate capacity analysis be performed. It is the staff's position that for the design requirements associated with severe accidents, the review will be based on SECY-90-016 guidelines.

As stated above, SRP Sections 3.8.1 and 3.8.2 require that an analysis be performed to determine the ultimate structural capacity of the containment. These SRP sections require a report be submitted documenting the analysis, including the failure mode and the criteria used to establish failure. For steel containments, Section 6.6.2.4 of Chapter 5 of the Evolutionary Requirements Document defines the ultimate structural capacity as the pressure and temperature loading that corresponds to the collapse load defined by the method detailed in Paragraph II-1430 of the ASME Code, Section III, Appendix II. Paragraph II-1430 describes the criterion (or procedure) for determining collapse load in an experimental stress analysis. It is not clear how this criterion for determining test collapse load will be used in an analysis. Plant designers intending to use this criterion will be required to show the method for applying the test collapse load to the final design analysis. The staff will evaluate this matter during its review of an individual application for FDA/DC.

Besides providing the steel containment criteria, Section 6.6.2.4 of Chapter 5 also defines the ultimate structural capacity of concrete containments. EPRI defines the ultimate capacity of a concrete containment to be the pressure and temperature loading that produces liner plate strains equal to the liner strain limits of ASME Code, Section III, Subarticle CC-3720 for the factored load category. Section 6.6.2.4 requires that the ultimate capacity analysis consider the penetrations and their interaction with the containment, the shield building, and other structures internal or external to the containment, which might cause localized failure before the limit load for the overall pressure boundary is reached. This criterion for concrete containment is acceptable. However, the staff will require that plant designers discuss how the results from testing prototype details or models of prototype details will be used to augment such analysis as stated in Section 6.6.2.4. The staff will evaluate this matter during its review of an individual application for FDA/DC.

In its letter dated April 24, 1991, the staff asked EPRI to provide guidance regarding the allowance for corrosion of carbon steel containment boundaries. In its reply dated July 2, 1991, EPRI stated that specific requirements concerning allowance for corrosion of carbon steel containment structures are given in Sections 4.3.4.1.1 and 4.3.4.1.2 of Chapter 6. This issue is addressed in Section 2.1 of Chapter 6 of this report.

6.6.2 Cavity/Pedestal-Drywell Configuration, Debris Coolability

To limit direct containment heating, Section 6.6.3 of Chapter 5 states that the cavity/pedestal-drywell configuration should be designed to preclude entrainment of core debris by gases ejected from a failed reactor vessel. To promote long-term debris coolability, EPRI states that the cavity floor should be sized to provide 0.02 m^2/MWt. EPRI specifies that the containment should be designed to ensure adequate water supply to the floor and that an alternative means of introducing water into the containment, independent of normal and emergency ac power, should be provided. Passive schemes for flooding the floor areas beneath the vessel are proposed and described in general terms for both BWRs and PWRs. Section 4.3.2.6.2 of Chapter 6 also indicates that the steel shell or liner of the containment should be protected from core debris by at least 3 feet of concrete.

In its DSER for Chapter 5, the staff stated that ALWR reactor vessel depressurization capability and cavity design features to entrap ejected core debris constitute an acceptable approach to the issue of high-pressure melt ejection. However, EPRI had not yet provided specific design criteria for these features in the Evolutionary Requirements Document. In SECY-90-016 and the DSER for Chapter 5, the staff concluded that vendors could resolve this issue if their designs for the evolutionary ALWR include

- sufficient reactor cavity floor space to enhance debris spreading
- a provision for quenching debris in the reactor cavity

In its SRM dated June 26, 1990, the Commission approved the staff's position.

In addition, the staff indicated in SECY-90-016 that it was evaluating the level of protection afforded by covering the containment liner and other structural members with concrete. The staff concluded that it may be necessary to protect these structural components with concrete.

The Evolutionary Requirements Document gives a number of design features that are intended to mitigate the effects of a molten core. Among other features, EPRI is proposing a floor sizing criterion of 0.02 m^2/MWt and provisions to flood the lower drywell or reactor cavity. The staff neither supports nor disputes the EPRI floor sizing criterion of 0.02 m^2/MWt. Instead, it concludes that it is appropriate to review the specific vendor designs to determine how the vendors addressed the three items discussed above to increase the level of protection relative to core debris coolability. The staff concludes that the "core on the floor" accident will not be considered as a new design-basis accident. However, the staff expects the vendors to consider the effects of core-concrete interaction on the production of noncondensible gases, the release of additional fission products from the core-concrete interaction, and additional heat and hydrogen generation in the new designs.

The three criteria discussed above are intended to ensure that the ALWR vendors provide measures to the extent practical to mitigate severe accidents while avoiding turning severe accidents into traditional design-basis accidents (DBAs). As the staff neither supports nor disputes particular floor sizing criteria, vendors should ensure that the containment can withstand the pressure increases caused by core-concrete interactions. For the range of severe accidents of concern, the vendors should realistically estimate the amount of core-concrete interaction that will occur, and ensure that the containment will accommodate the resultant conditions for at least 24 hours. Where insufficient data exist to develop realistic estimates, the vendor may propose such alternatives as additional tests or the use of other methodologies for determining the degree of core-concrete interaction. The ALWR vendors should also perform parametric studies to determine how sensitive the containment response is to variations in the amount of core debris that is available to interact with the concrete. The staff concludes that incorporating the mitigative measures to the extent practical and ensuring containment integrity for a 24-hour period will provide defense in depth as well as appropriate degree of robustness in the containment design.

In the draft Commission policy paper dated February 27, 1992, the staff recommended that, in addition to the two items above, the Commission approve the staff's position that the evolutionary designs

- protect the containment liner and other structural members with concrete, if necessary

- ensure that the containment can accommodate the pressure increases resulting from core-concrete interactions involving a range of scenarios that release core debris into the containment for 24 hours following the start of a severe accident

Since the Commission has not yet reviewed this approach to resolving the issue of core debris coolability, it does not represent an agency position. Therefore, the staff regards this as an open issue that will be closed once the Commission approves this resolution or provides alternative guidance.

Details of the reactor cavity and drywell configurations are in Chapter 6. See also Sections 5.5 and 6.6.5 of Chapter 5 of this report for the staff's evaluation of the safety depressurization and vent system. This item is also addressed in the regulatory departure analysis in Appendix B to Chapter 1 of this report.

6.6.3 Containment Heat Removal

Section 6.6.4 of Chapter 5 of the Evolutionary Requirements Document states that containment heat should be removed by means of systems provided for mitigating DBAs. For BWRs, this will be achieved by suppression pool cooling using the residual heat removal system. For PWRs, this will be achieved by using the containment spray system (fan coolers will not perform this function).

By reference to 10 CFR 50.34(f), 10 CFR Part 52 requires future plants to "provide one or more dedicated containment penetrations, equivalent in size to a single 3-foot-diameter opening, in order not to preclude future installation of systems to prevent containment failure, such as a filtered vented containment system." In its DSER for Chapter 5, the staff stated that the Evolutionary Requirements Document did not address compliance with this regulation. The staff anticipated that it may not be necessary to incorporate a 3-foot-diameter opening to satisfy the containment performance guidelines, and stated that EPRI should justify an exemption to this requirement. The staff concluded that it would review the acceptability of the containment heat removal provisions in the Evolutionary Requirements Document in conjunction with its review of the containment performance criteria for a severe accident (see Section 2.1 of this chapter).

In Section 6.6.2.6 of Revision 3 to Chapter 5, EPRI states that as an alternative to increasing the containment volume and containment pressure capability to accommodate the various accident sequences, overpressure protection may be provided by an overpressure protection system. EPRI also states that there should be a significant decrease in the residual public risk due to the addition of such a system. EPRI proposes that the need for containment overpressure protection be determined on a design-specific basis.

The staff agrees that the need for containment overpressure protection for the evolutionary plant should be evaluated on a design-specific basis. The staff will review an individual application for FDA/DC against the criteria in SECY-90-016. This DSER open issue is closed. This issue is also discussed in Section 2.5.3 of Appendix B to Chapter 1 of this report.

6.6.4 Fission Product Control

The Evolutionary Requirements Document states that fission product leakage control and scrubbing capability for severe accidents will be provided by the systems that will mitigate DBAs.

In its DSER for Chapter 5, the staff concluded that taking credit for systems intended primarily for mitigating design-basis events (i.e., cooling water systems, containment spray systems, and fission product barriers) in demonstrating that the public safety goal is met and adequate severe-accident mitigation is provided was acceptable, provided it is demonstrated that this equipment can function under severe-accident conditions. The staff's position with respect to equipment survivability under severe-accident conditions is discussed in Section 6.6.6 of this chapter.

Section 6.6.4.2 of Chapter 5 states that fission product control systems will be provided for severe accidents. Section 6.6.5.4 states that equipment identified as useful for severe-accident mitigation will have the capability to perform their function during a severe accident. The staff agrees that the equipment should be capable of functioning during a severe accident. However, further assurance is needed that the equipment will function.

SECY-90-016 states that mitigation features must be designed so there is reasonable assurance that they will operate when needed during a severe-accident sequence. Also, there should be high confidence that this equipment will survive severe-accident conditions for the period that it is needed to perform its intended function. The plant designer has the responsibility to specify the severe-accident environment in which the equipment is expected to function and to document the basis for the determination that the equipment will function during that severe accident.

The staff concludes that EPRI has justified its position for using certain plant equipment designed for DBAs. However, the plant designer must demonstrate that the equipment designed for DBAs and proposed for use in severe accidents can perform its function in a severe-accident environment. The staff will review an individual application for FDA/DC against the criteria in SECY-90-016. This DSER open issue is closed.

6.6.5 RCS Depressurization Capability

The Evolutionary Requirements Document states that a safety-grade reactor coolant system (RCS) safety depressurization and vent system (SDVS) will be provided. In Section 5.5 of this chapter, the design requirements for the SDVS are described.

As stated in Section 6.6.2 of this chapter, the staff concludes that reactor vessel depressurization capability combined with cavity design features to entrap ejected core debris constitutes an acceptable approach to the issue of high-pressure core-melt ejection. However, in its DSER for Chapter 5, the staff stated that the Evolutionary Requirements Document did not specify a criterion for the depressurization rate of the SDVS during a severe accident. The staff concluded that the capacity of the depressurization system should be defined by DBA requirements as well as by requirements that exceed the design basis (including primary feed and bleed during a total loss of feedwater and severe-accident scenarios) and should be taken into consideration during the development of procedures for managing accidents. During a high-pressure core-melt scenario, the RCS depressurization system should provide a rate of RCS depressurization to preclude molten-core ejection and to reduce RCS pressure sufficiently to preclude creep rupture of steam generator tubes. Primary systems of evolutionary ALWRs should have the capability to be depressurized shortly after loss of design-basis decay heat removal to avoid a rapid release to the containment of large quantities of hydrogen produced in-vessel that could have the potential for overwhelming the igniters upon vesse failure and to avoid induced steam generator tube rupture in PWRs.

In Section 5.4 of this chapter, the staff states that Revision 3 of Chapter 5 of the Evolutionary Requirements Document requires that the safety depressurization and vent system be capable of reducing RCS pressure to 250 psig or less before reactor vessel melt-through, as a means to preclude containment challenges through direct containment heating. The staff concludes that this is an acceptable design objective. Therefore, this DSER open issue is closed. See Section 5.5 of this chapter for additional information on this matter.

6.6.6 Equipment Survivability

In Section 6.6.5.3 of Revision 0 to Chapter 5 of the Evolutionary Requirements Document, EPRI stated that equipment important for managing a severe accident will be "specified to licensing design basis events requirements" but will not necessarily meet DBA quality standards. EPRI further stated that the designer/applicant should assess operating margins to provide "reasonable assurance that the equipment can function during severe accident conditions for a defined period of time (i.e., hours or days)." Equipment will be located to avoid areas of potential standing hydrogen flames. In its letter dated August 16, 1988, EPRI indicated that the IDCOR (Industry Degraded-Core Rulemaking Program) approach will be used in the assessment. The IDCOR methodology is described in a letter from A. E. Scherer (EPRI) to F. J. Miraglia (NRC) dated September 9, 1988 (Advanced Reactor Severe Accident Program (ARSAP) Topic Paper Set 4).

In its DSER for Chapter 5, the staff stated that it agreed that features provided for severe-accident protection only (not required for DBA) should not be subject to the environmental qualification requirements in 10 CFR 50.49, the quality assurance requirements in 10 CFR Part 50, Appendix B and the redundancy/diversity requirements in 10 CFR Part 50, Appendix A. However, mitigation features must be designed to operate in the severe-accident environment for which they are intended and over the time span for which they are needed. The staff concluded that the Evolutionary Requirements Document should specify a criterion that severe-accident mitigation equipment should be capable of being powered from an alternate power supply as well as from the normal Class 1E onsite systems. Although the Evolutionary Requirements Document did not specify this criterion, the criteria specified for electrical systems in the document appeared to meet it. The staff further stated that a demonstration of equipment survivability should also consider the circumstances of applicable initiating events (e.g., station blackout, earthquakes) and the environment (e.g., pressure, temperature, radiation) in which the equipment is relied on to function. Appendices A and B to RG 1.155, "Station Blackout," give additional guidance on quality assurance activities and specifications that are appropriate for equipment used to prevent and mitigate the conse-quences of severe accidents.

SECY-90-016 describes the staff's position on equipment survivability during a severe accident. However, the systems used to mitigate the severe accident must survive in the severe-accident environment and be capable of being powered by an alternate power supply in addition to the normal Class 1E power supply. In Section 6.6.5.4 of Revision 3 to Chapter 5, EPRI described the requirements for equipment survivability during a severe accident, and stated that the equipment is not required to be subject to 10 CFR 50.49 relative to environmental qualification or the requirements of Appendix A or B to 10 CFR Part 50. This position is in agreement with SECY-90-016. However, Section 6.6.5.4 does not address the classification of the alternate power supply or the normal power supply. The staff concludes that the plant designer must address the survivability of the power supply and an alternate power supply. In particular, if a Class 1E power supply is not provided, the designer must demonstrate that the selected power supply will achieve the necessary reliability goals of the system.

The staff concludes that EPRI's position relative to not subjecting the severe-accident equipment to the requirements of 10 CFR 50.49 and Appendices A and B to 10 CFR Part 50 are acceptable. However, the adequacy of the power supply has been left to the specific design. The staff will review an individual application for FDA/DC against the criteria in the SRP and SECY-90-016 in this regard. This DSER open issue is closed.

6.6.7 Containment Mixing Provisions

Section 4.3.2.5 of Chapter 6 describes geometrical configurations inside the containment to reduce the probability of hydrogen flame acceleration and deflagration-to-detonation transition. Hydrogen generation and ignition are discussed in Sections 2 and 6.5 of this chapter. Containment atmosphere mixing is discussed in Chapter 6 of this report.

6.6.8 Severe-Accident Management

It has long been recognized by both the NRC and industry that while reactor design is in itself extremely important in providing protection against the threat of severe accidents, operator intervention could also have a major impact on reducing accident risk. Given appropriate training and certain modest equipment features for accident management, including accident monitoring instrumentation, there could be significant opportunities for operator action in both precluding core damage and mitigating accidents that progress to meltdown and vessel failure. In early 1988, a cooperative effort was initiated with participation by the NRC, the Nuclear Management and Resources Council (NUMARC), EPRI, and other industry representatives to develop an overall approach to accident management. In SECY-88-147, "Integration Plan for Closure of Severe Accidents," and Generic Letter 88-20, the staff identified the development of an accident management plan by each licensee as an essential ingredient of the "closure" process for severe accidents. However, Generic Letter 88-20 did not require that an accident management plan be developed as an integrated part of the individual plant examination, on the basis that the staff was currently working with NUMARC to develop further guidance on this matter.

A comprehensive description of the objectives and planned approach to accident management was subsequently provided in SECY-89-012, "Staff Plans for Accident Management Regulatory and Research Program." Improvements in current utility capabilities in five general areas were also identified in this paper. Improvements in these areas would be achieved through the development and implementation by each utility of an "accident management plan."

In support of this activity, industry has initiated a program on accident management described in SECY-90-313, "Status of Accident Management Program and Plans for Implementation." Industry efforts are being coordinated by NUMARC and involve the participation of EPRI and the owners group for each reactor vendor. The industry program involves three major activities that are currently scheduled to be completed by 1993.

The NRC is continuing to work with industry toward resolving of accident management issues. Key activities in the resolution process include completion and NRC review of the NUMARC process for evaluating accident management capabilities, and the vendor-specific accident management guidance. Subsequently, the NRC will issue a letter to all licensees providing guidance on developing an accident management plan and requesting each licensee to develop and implement such a plan. Current plans are to issue this letter in late 1993. The generic letter will address the role of industry products in the development of the desired utility accident management capabilities and will provide further guidance as needed.

In its DSER for Chapter 5, the staff stated that the Evolutionary Requirements Document made no commitment to use the severe-accident management information gained from this program, specifically such design information as identification of equipment useful for accident management. In Section 2.3.3.8 of Revision 1 of Chapter 1 of the Evolutionary Requirements Document, EPRI includes additional requirements in this area. This section requires that a technical basis for a severe accident management program, including emergency procedure guidelines (EPGs), to ensure core-damage prevention and mitigation, including meeting offsite dose limits, will be developed by the plant designer. The plant designer will use the plant-specific PRA and other relevant information to confirm that the plant design is compatible with the EPGs and severe-accident management program. As discussed in Section 2.3.3 of Chapter 1 of this report, the staff concludes that these requirements are consistent with the Commission's severe accident policy. The staff concludes that these requirements, while consistent with the Commission's severe accident policy, do not go far enough in clarifying the responsibility of the ALWR designer to explicitly address ALWR accident management capabilities/features as part of the design process. While it is premature for advanced reactor vendors to submit detailed plans for accident management, since methods and guidance on developing such plans are still being developed as part of the accident management program, it is appropriate for vendors to consider accident management aspects of the advanced reactors at the design stage. This should include the development of accident management strategies, such as those identified in Generic Letter 88-20, Supplement 2, and/or the incorporation of design features to facilitate (or eliminate the need for) implementation of a strategy. The motivation for addressing accident management measures at the design stage is that, if identified early, specific provisions can be made in the plant design to facilitate such measures (e.g., automation of otherwise manual actions or the use of remote-manual rather than local manual valves). The PRA should be used as a tool for identifying and assessing potential accident management measures.

The advanced reactor vendors should also identify, to the extent practical, a path to resolving accident management, and the respective responsibilities of the vendor and the combined license applicant for addressing each of the five elements of accident management. Vendors are in a position to do this since the elements and scope of accident management have been reasonably well defined, and because draft methods and guidance on developing accident management plans are current available (e.g., the "Process for Evaluating Accident Management Capabilities" developed by NUMARC, and the "Severe Accident Management Guidance Technical Basis Report" developed by EPRI).

As part of its review of an individual application for FDA/DC, the staff will perform a preliminary review of (1) the accident management features/capabilities of each ALWR design and (2) the vendor's plans and commitments for developing the detailed accident management plan. A more detailed assessment will be performed by the staff after the ALWR design details have been established and each of the elements of accident management have been addressed by an applicant for a combined license. With this clarification, this DSER open issue is closed.

6.6.9 Externally Initiated Severe Accidents

Evidence from previous PRAs and other severe-accident studies indicates that externally initiated severe accidents can represent a significant contribution to overall plant risk. Appendix A to Chapter 1 of the Evolutionary Requirements Document includes information on EPRI's proposed approach for addressing external events. The staff's evaluation of this issue is in Appendix A to Chapter 1 of this report.

7 BWR MITIGATION/CONTAINMENT REQUIREMENTS

7.1 Introduction

Section 7 of Chapter 5 of the Evolutionary Requirements Document specifies mitigation requirements applicable to the BWR version of the ALWR. The Evolutionary Requirements Document states that the containment system for the ALWR BWR will include a pressure-suppression pool, drywell, wetwell airspace, and drywell/wetwell vent system in a steel-lined, reinforced-concrete containment vessel. A reactor building will be integral with and surround the primary containment, serving as a fission product leakage control barrier. The Evolutionary Requirements Document states that the containment system, operating in conjunction with other plant systems, must limit fission product leakage from a postulated loss-of-coolant accident (LOCA) to values no greater than those required to meet both the control room dose limits of GDC 19 of Appendix A to 10 CFR Part 50 and the offsite dose limits of 10 CFR Part 100.

BWR containment protection from reverse pressurization is described in Chapter 6. The BWR secondary containment function will be provided by the fission product leakage control system described in Section 6.4 of Chapter 5 and Section 4.4 of Chapter 6. The staff's review of that system is given in the corresponding sections of this report.

7.2 Performance Requirements

In Sections 7.2.5 and 8.1.2.4 of Revision 0 of Chapter 5 of the Evolutionary Requirements Document, EPRI stated that containment subcompartment pressure capability will be evaluated in accordance with Section 3 of Revision 0 of Appendix A to Chapter 1 of the Evolutionary Requirements Document. This section indicated that the leak-before-break criterion is to be used to eliminate the need to consider the dynamic effects of pipe breaks, including rapid subcompartment pressurization. In its DSER for Chapter 5, the staff stated that, although the recent revision to GDC 4 allows this approach to be taken and, therefore, is acceptable for the narrow case of design-basis accidents (DBAs), the staff was concerned about subcompartment performance during accidents that go beyond DBAs. For example, the capability of the reactor cavity design to mitigate severe accidents may be jeopardized by the literal application of this approach. The staff concluded that EPRI should address the effect of this approach with respect to severe-accident mitigation.

In Section 6.6.2.5 of Revision 1 to Chapter 5, EPRI stated that localized pressure in the reactor cavity or lower drywell will be considered in the evaluation of severe-accident events. These events will include such sequences as low-pressure-melt ejection and core debris interaction. The commitments in the Evolutionary Requirements Document are consistent with the staff's position as described in SECY-90-016. However, additional criteria for ALWRs specified in both SECY-90-016 and the staff requirements memorandum (SRM) dated June 26, 1990, include the need for

- a reliable depressurization system
- cavity design features to decrease the amount of ejected core debris that reaches the upper containment

Because these requirements can only be implemented during the design of the system, the staff expects to evaluate the capability of the reactor cavity and the lower drywell area of each specific design against the criteria in SECY-90-016 and the SRM dated June 26, 1990. The staff will also evaluate the bases on which the applicant has concluded that the design has satisfied all of these criteria. Therefore, the staff will evaluate this matter during its review of an individual application for FDA/DC. This DSER open issue is closed.

Section 7.2.1 of Chapter 5 states that the containment design conditions will be based on the limiting double-ended guillotine break (LOCA). Since the BWR has no external recirculation system, the DBA LOCA will not be a recirculation-line break. The Evolutionary Requirements Document states that leak-before-break methodology may be used where possible in subcompartment pressurization analyses consistent with the "broad scope rule" modification to GDC 4 (see 53 FR 11311, "Supplementary Information"). The staff's evaluation of leak before break is given in Section 4.5.5 of Chapter 1 of this report.

In Section 7.2.24 of Revision 0 to Chapter 5 of the Requirements Document, EPRI stated that main steam isolation valve (MSIV) leakage is assumed to be 500 to 1000 scfm (standard cubic feet per minute). EPRI indicated that this was a typographical error ("scfm" should be "scfh" (standard cubic feet per hour)). In its DSER for Chapter 5, the staff stated that this value, nevertheless, represented a significant increase with respect to current practice. The staff concluded that EPRI had provided insufficient justification to support the proposed MSIV leakage rate.

In Section 1.2.3.5 of Revision 1 to Chapter 5, EPRI stated, in part, that the BWR MSIV total allowed leakage rate, assumed for the licensing-design-basis (LDB) dose calculation, will be 35 scfh at design pressure for each main steamline. The staff will assess this value using a radiological analysis for the potential source of containment atmospheric leakage during its review of an individual application for FDA/DC. The calculated dose will be required to meet regulatory requirements.

However, direct cycle of a BWR plant results in the transport of some radioactivity from reactor coolant to steam, condensate, and the feedwater system. In Section 5.3.3.9 of Chapter 3, EPRI states that a separate MSIV leak detection and control (MSIV-LCS) will not be provided. EPRI is taking credit for the mitigative capabilities of the main steamlines, the bypass lines, and the condenser. Section 5.3.3.8 of Chapter 3 states that the main steam-lines will be designed as seismic Category I from the reactor vessel to the seismic restraint located between the MSIV and the turbine stop valve and Quality Group A from the reactor vessel to and including the outboard MSIV. The staff is continuing its review of EPRI's models for holdup, plateout, and resuspension in the main steamlines, the bypass lines, and the condenser. In order to accept the mitigative capabilities of the main steamlines and the condenser, the staff would need to find these models acceptable and would require the main steamlines, up to and including the turbine stop valve, and the bypass lines to be designed to seismic Category I and Quality Group B standards, and the condenser would be required to be seismically qualified. The staff's proposed resolution for BWR main steamline classification is in Section 2.3.1 of Appendix B to Chapter 1 of this report.

By letter dated March 18, 1988, the staff stated that EPRI should address the criteria for maximum allowable suppression pool bypass leakage. Section 7.2.17 of Revision 1 to Chapter 5 of the Requirements Document requires a vacuum breaker system design that will preclude steam bypass or, as an alternative, consideration of reverse vent clearing. These provisions are intended for mitigative design-basis accidents without relying on containment spray, thus enabling the containment spray system to be designed to non-safety-grade standards. The staff does not accept this position. Because the ALWR BWR design requirements do not provide for safety-related fan coolers, the BWR design, in the absence of engineered safety features (ESF)-grade sprays, does not provide for any active containment atmosphere heat removal system that would be designed to the requirements for an ESF system (e.g., Quality Group B, seismic Category I). The staff concludes that an ESF containment spray system is a necessary component in a pressure-suppression containment design because of the benefits associated with mitigation of steam bypass as well as reduction of the containment atmosphere temperature following steamline breaks (in which the containment atmosphere is superheated). Since spray systems also mitigate the consequences of certain pool dynamic load phenomena (chugging loads) and provide for effective containment atmosphere mixing, the staff concludes that containment sprays are sufficiently important to warrant the more stringent requirements associated with ESF systems. The staff will evaluate this matter during its review of an individual application for FDA/DC. This DSER open issue is closed. (See also Section 4.4 of this chapter.)

7.3 Equipment Design Requirements

Section 7.3 of Chapter 5 of the Evolutionary Requirements Document requires the suppression pool and associated airspace to be enclosed. This feature, provided by a steel-diaphragm-lined floor, is intended to prevent the potential spread of radioactivity in the pool water into operating areas and to keep the pool water from being contaminated by material falling into the pool. It also provides for separation of the containment from equipment areas required to be accessible during operation, making practical the use of inerting for combustible gas control. The Evolutionary Requirements Document specifies that the suppression pool will be sized to accommodate the DBA without an "upper pool dump" as required by the Mark III containment design. The staff concludes that these features do not conflict with SRP Section 6.2.1.1.C, "Pressure-Suppression-Type BWR Containments," and are, therefore, acceptable, subject to its final review of more detailed information during the review of an application for FDA/DC.

For severe-accident mitigation, capability will be provided to gravity dump a limited amount of the suppression pool water into the lower drywell in order to provide core debris cooling as described in Section 6.6.2 of this chapter.

8 PWR MITIGATION/CONTAINMENT REQUIREMENTS

8.1 Primary Containment

The Evolutionary Requirements Document states that the PWR containment should be designed to provide a leak-tight barrier to prevent uncontrolled release of radioactivity in the event of a postulated accident. The Evolutionary Requirements Document describes the PWR containment as a "large, dry type containment." Chapter 6 further indicates that a steel-cylinder type is preferred and that a containment spray system to remove containment heat and provide fission product control should be included in the design.

Section 8.2.4.2 of Chapter 5 states that:

- The containment design pressure and temperature must be equal to or greater than the pressure and temperature conditions resulting from postulated loss-of-coolant, steamline-, or feedwater-line-break accidents.

- The containment will have sufficient free internal volume to ensure that the concentration of hydrogen inside the containment is less than 13 percent by volume, based on uniformly distributed concentrations of hydrogen generated by the equivalent of a 75-percent active fuel cladding-water reaction during an accident.

In Section 2.4.1.3 of Revision 0 of Chapter 5 of the Evolutionary Requirements Document, EPRI stated that at the preliminary design stage, a margin will be provided between calculated peak pressure and design pressure of 10 percent for dry containments and 15 percent for pressure-suppression containments. This requirement has been deleted from Section 2.4.1.3. The deletion of this requirement is acceptable because the margin between calculated peak pressure and containment design pressure is only applicable at the construction permit stage of the licensing review. The evolutionary ALWR design will be licensed under 10 CFR Part 52; therefore, the information required will be that required in a final safety analysis report. The requirements of Section 8.2.4.2 of Chapter 5 conform to the NRC criteria in SRP Section 6.2.1.1.A, "PWR Dry Containments, Including Subatmospheric Containments," and are, therefore, acceptable.

The Evolutionary Requirements Document states that the containment must be designed to ensure that adequate protection exists from external pressure conditions that may result, for example, from inadvertent actuation of containment spray systems. This external pressure design criterion conforms to the NRC criteria in SRP Section 6.2.1.1.A and is, therefore, acceptable.

Section 8.2.5.2 of Chapter 5 requires that instrumentation be provided to monitor conditions within the containment during and following an accident. This instrumentation will include the capability for measuring containment radioactivity, hydrogen (or oxygen) concentration, pressure, temperature, and in-containment refueling water storage tank (IRWST) level. This criterion for instrumentation related to containment functional design conforms to the NRC acceptance criteria in SRP Section 6.2.1.1.A and is, therefore, acceptable.

Containment Design Leak Rate

In Sections 1.2.3.5 and 8.2.4.5 of Chapter 5, EPRI states that (1) the containment leak rate allowance must be 0.5 percent per day or greater at design pressure in order to provide more operating flexibility for containment leak rate testing and associated maintenance, while still meeting 10 CFR Part 100 dose criteria for design-basis events, and (2) the containment leakage varies as a function of containment pressure.

In its DSER for Chapter 5, the staff stated that these positions represent significant relaxations of the containment leak rate. Although the rationale portion for the position stated in Section 8.1.2.5 of Chapter 5 notes that the containment features will be selected to minimize leakage, the incentive to increase leakage to 0.5 percent per day is also stated to include a reduced need to maintain valve leakage integrity and avoid lost power generation associated with the inability to satisfy containment integrated leakage rate requirements. The staff was concerned that, in large measure, the basis for these relaxations comes from the application of new source-term approaches.

At present, the containment design leak rate is not a fixed value, but is determined as that value which, in combination with other plant and site parameters, will result in calculated doses not exceeding the values given in 10 CFR Part 100 as a result of the accident postulated and evaluated using Regulatory Guides (RGs) 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors," and 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors." Typical containment design leak rates have been 0.1 to 0.2 percent per day for single-containment PWRs and about 0.5 percent per day or more for BWRs with typical standby gas treatment and main steam isolation valve leakage control systems. However, the minimum acceptable design containment leakage will not be less than 0.1 percent per day. RG 1.4 specifies that for PWRs the containment leak rate is assumed to remain constant for 24 hours and reduce to half the design leak rate afterwards. For BWRs, RG 1.3 specifies that the containment leak rate remains constant for the duration of the accident.

In its letter dated May 22, 1991, EPRI stated that the ALWR containment features will be selected to minimize leakage but there is incentive to use a design-basis leakage rate of 0.5 percent per day, compared to 0.1 to 0.2 percent per day at current plants, in order to minimize leakage rate testing requirements. This will reduce personnel exposure associated with the repair of containment isolation valves and will avoid lost power generation associated with the inability to satisfy containment integrated leakage rate requirements. In addition, Section 8.3.2.1.1 of Revision 1 to Chapter 5 specified that the containment spray system must have sufficient capability to reduce containment pressure to less than 50 percent of the containment design pressure within 24 hours after a design-basis accident (DBA).

10 CFR Part 100 requires that, as an aid in evaluating a proposed nuclear power plant site, an applicant assume the expected demonstrable rate of leakage from the containment. Leak testing experience at nuclear power plants shows that a design rate of 0.1 percent per day provides adequate margin above typical measured containment leak rates and is compatible with current leak test methods and test acceptance criteria. Therefore, the minimum acceptable design containment leakage rate will not be less than 0.1 percent per day.

The staff concludes that the assumed 0.5-percent containment leakage rate will be evaluated to meet 10 CFR Part 100 dose requirements based on a new source-term analysis and the actual dose rate may be lower than using current source-term analysis. Features of containment structure and its associated penetration designs could minimize actual leakage much less than the allowable leakage limit. Therefore, the staff concludes that the 0.5-percent allowable containment leakage is acceptable provided the calculated doses for a DBA meet the dose requirements of 10 CFR Part 100.

The staff has also reviewed EPRI's position on containment leakage rate varying as a function of containment pressure. The staff recognizes that the current guidance of constant or near-constant containment leak rates in RGs 1.3 and 1.4 provides substantial margins when compared to varying the leakage rate as a function of pressure. However, since the regulatory guides were published, knowledge of the phenomenology of the effects of containment pressure on the leakage rate has increased. The staff has determined that pressure curves can be conservatively developed that provide adequate margin without resorting to the restrictive guidance of RGs 1.3 and 1.4. Therefore, EPRI's position on variation in containment leakage as a function of containment pressure is acceptable provided leak tests are performed periodically to reconfirm the pressure leak rate profiles described. The staff will evaluate this matter during its review of an individual application for FDA/DC or combined license. This DSER open issue is closed.

In Sections 7.2.5 and 8.1.2.4 of Chapter 5 of Revision 0 of Chapter 5 of the Evoluntionary Requirements Document, EPRI stated that containment subcompartment pressure capability will be evaluated in accordance with Section 3 Revison 0 of of Appendix A to Chapter 1 of the Evolutionary Requirements Document. Section 3 indicated that the leak-before-break criterion is to be used to eliminate the need to consider the dynamic effects of pipe breaks, including rapid subcompartment pressurization. The staff's evaluation of this issue is in Section 7.2 of this chapter.

8.2 Containment Spray System

In Section 8.3.1.2 of Chapter 5, EPRI states that the function of the containment spray system (CSS) is to reduce the containment temperature and pressure following a LOCA or secondary system pipe rupture accident inside the containment by removing thermal energy from the containment atmosphere. In addition, the Evoltionary Requirements Document states that the CSS should be designed to remove fission products from the containment atmosphere in order to reduce the inventory of fission products available for leakage from the containment. The document states that the CSS should consist of an IRWST that is shared by two independent, 100-percent-capacity trains. Each train should contain a containment spray (CS) pump, a heat exchanger, a suction line from the IRWST, a discharge line to the containment spray headers, and associated piping, valves, instrumentation, and controls.

The Evolutionary Requirements Document requires that the CS pumps be identical to the RHR pumps. Interconnections should be provided to permit the use of an RHR pump as a backup to a CS pump if a CS pump is out of service. In addition, the CSS design will ensure that required pump net positive suction head (NPSH) is available for all operating conditions. Supporting analyses will account for suction piping and other head losses. No credit will be taken for coolant subcooling or elevated containment pressure. The IRWST level will be assumed to be at the minimum value calculated during CSS operation, assuming worst-case instrumentation errors. The suction connection to the IRWST will be designed to ensure that vortexing cannot occur.

The staff concludes the provisions discussed above are consistent with the guidance of SRP Section 6.2.2, "Containment Heat Removal Systems," and are, therefore, acceptable.

Section 8.3.2.2.2 of Chapter 5 specifies that the spray water will not contain additives, such as sodium hydroxide, for maintaining basic pH in order to enhance the removal of fission products. In Section 4.3 of the source-term report for the evolutionary plant design dated October 18, 1990, EPRI stated that "the importance of controlling pH in this situation [during an accident] is clear, and so it is assumed here that measures will be taken in ALWRs to assure that the pH of the containment water is maintained in an all-saline state for the accident duration."

In revised SRP Section 6.5.2, "Containment Spray as a Fission Product Cleanup System," the staff acknowledges that a chemical additive is not required during spray injection, but that pH should be maintained at 7 or above during the entire duration of an accident to minimize the formation of elemental iodine in the containment water and revaporization into the containment atmosphere. A pH control is also required by Branch Technical Position MTEB 6-1 (SRP Section 6.1.1, "Engineered Safety Features Materials"), which specifies a basic environment for preventing corrosion of austinitic stainless steel. The staff concludes that Section 8.3.2.2.2 of Chapter 5 regarding the elimination of additives is acceptable. As discussed in Section 2.5.2.2 of Appendix B to Chapter 1 of this report, this DSER open issue is closed. However, an applicant for a combined license will be required to submit a description of the methods to ensure proper postaccident pH control is maintained for iodine control and for protection of austenitic steels.

Section 8.2.3.9.2 of Revision 0 of Chapter 5 specified a fouling factor of 0.0005 for the design of CS heat exchangers. The staff questioned EPRI on the selection of this value. In its August 16, 1988, response, EPRI indicated that 0.001 would be used for the CS heat exchangers. The staff concludes that a fouling factor of 0.001 is acceptable and is consistent with Standard T-2.41 of the Tubular Heat Exchangers Manufacturers Association.

In its letter dated August 16, 1988, EPRI committed to revise Section 8.2.3.13.2 of Revision 0 of Chapter 5 to specify the capability for manual (in addition to automatic) actuation of the containment spray system. In the DSER for Chapter 5, the staff concluded that the modification was acceptable because it was consistent with Institute of Electrical and Electronics Engineers (IEEE) 279.

In its letter dated May 22, 1991, EPRI stated that it had added Section 8.2.3.1 to Chapter .0 of the Evolutionary Requirements Document to state:

> The M-MIS [man-machine interface systems] for the protection and safety systems shall normally provide for automatic startup or actuation. That is, the condition which requires the protection or safety action shall initiate the appropriate system action without operator action. The operators, however, shall also be able to manually initiate the system action.

Because the added requirement is applicable to manual actuation of the containment spray system, the staff concludes that this modification acceptably resolves this issue. Therefore, this DSER confirmatory issue is closed.

8.3 Fission Product Removal and Control System

The fission product removal and control function for the PWR is provided by the containment spray system described in Section 8.2 (above).

9 CONCLUSION

Subject to resolution of the identified open issue, the staff concludes that the EPRI requirements established in Chapter 5 of the Evolutionary Requirements Document for engineered safety systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine that the plant-specific engineered safety systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the Standard Review Plan (NUREG-0800), or provide justification or alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 5 of the Evolutionary Requirements Document specifies requirements that, subject to resolution of the identified open issue and the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose engineered safety systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment. In addition to complying with existing regulations, such a facility would also be consistent with Commission policies for severe-accident protection.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 5 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
GENERIC SAFETY AND LICENSING ISSUES

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address the resolution of generic safety issues in Appendix B of each chapter. In DSER for Chapter 5, the staff evaluated EPRI's requirements to address the resolution of the following issues:

Issue A-44	Station Blackout
Issue A-45	Shutdown Decay Heat Removal Requirements
Issue A-48	Hydrogen Control Measures and Effects of Hydrogen Burns on Safety Equipment
Issue D.2	Emergency Core Cooling System Capability for Future Plants
Issue II.E.4.3	Containment Design - Integrity Check
Issue 70	Power-Operated Relief Valve (PORV) and Block Valve Reliability (PWRs)
Issue 84	Combustion Engineering (CE) PORVs
Issue 96	Residual Heat Removal (RHR) Suction Valve Testing
Issue 99	Reactor Coolant System (RCS)/RHR Suction Line Valve Interlock in PWRs
Issue 105	Interfacing System Loss-of-Coolant Accident at BWRs
Issue 117	Allowable Outage Times for Diverse, Simultaneous Equipment Outages
Issue 120	On-Line Testability of Protection Systems (Leakage Testing of Pressure Isolation Valves)
Issue 93	Steam Binding of Auxiliary Feedwater Pumps (PWRs)
Issue 121	Hydrogen Control for Large Dry Containments
Issue 122.1a	Davis-Besse Loss-of-All-Feedwater Event - Common Mode Failure of Auxiliary Feedwater Pump Discharge Isolation Valve Closed Position
Issue 122.1b	Davis-Besse Loss-of-All Feedwater Event - Excessive Delay in Recovery of Auxiliary Feedwater
Issue 122.1c	Davis-Besse Loss-of-All Feedwater Event - Adequacy of Emergency Procedures. Operator Training and Available Plant Monitoring Systems
Issue 124	Reliability of Auxiliary Feedwater System
Issue 125.II.7	Long-Term Generic Actions as a Result of the Davis-Besse Event of June 9, 1985 - Reevaluate Provisions To Automatically Isolate Feedwater From Steam Generator During Line Break
Issue 125.II.11	Long-Term Generic Actions as a Result of the Davis-Besse Event of June 9, 1985 - Recovery of Main Feedwater as Alternative to Auxiliary Feedwater
Issue 132	RHR Pumps Inside Containment

In Revision 1 to the Evolutionary Requirements Document, submitted by letter dated September 7, 1990, EPRI relocated its requirements to address generic safety issues that were unresolved as of January 1, 1990, to Appendix B to Chapter 1. As a result, a number of generic safety issues that were addressed in the original Evolutionary Requirements Document are no longer addressed. The staff has provided its evaluation of EPRI's requirements to address generic safety issues in Appendix B to Chapter 1 of this report and has also documented its closure of open and confirmatory issues associated with generic safety issues no longer addressed by EPRI. Therefore, as discussed in Section 3 of Appendix B to Chapter 1 of this report, the DSER open and confirmatory issues associated with Unresolved Safety Issues A-44 and A-48 and Generic Safety Issues II.E.4.3, 70, 84, 96, 99, 105, 120, and 121 are closed.

APPENDIX C
OPTIMIZATION SUBJECTS

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address EPRI-defined optimization subjects in Appendix C to Chapter 5. In the DSER for Chapter 5, the staff discussed Type C leakage rate testing intervals and source-term issues. In Revision 1 to the Evolutionary Requirements Document, submitted by letter dated September 7, 1990, EPRI relocated its discussion of optimization subjects to Appendix B to Chapter 1. The staff has provided its evaluation of EPRI's requirements to address these issues in Section 2 of Appendix B to Chapter 1 of this report.

APPENDIX D
REGULATORY DEPARTURE ANALYSIS

Appendix D to the DSER for Chapter 5 provided the staff's regulatory departure analysis required by the Commission staff requirements memorandum of August 24, 1989. Because this analysis affects the entire Evolutionary Requirements Document, the staff has provided this analysis in Appendix B to Chapter 1 of this report.

CHAPTER 6, "BUILDING DESIGN AND ARRANGEMENT"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 6, "Building Design and Arrangement," of the Evolutionary Requirements Document through Revision 3. Chapter 6 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering; Bechtel Power Corporation; Commonwealth Edison Company; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Sargent and Lundy Engineers; Stone and Webster Engineering Corporation; Westinghouse Electric Corporation; Yankee Atomic Electric Company; and EPRI.

On November 18, 1988, EPRI submitted Chapter 6 of the Evolutionary Requirements Document for staff review. By letters dated February 23, March 22, April 28, June 8, August 30, and November 11, 1989, the staff requested that EPRI supply additional information. EPRI provided the information in its responses dated July 3, August 18, October 19, and December 22, 1989, and January 18, 1990. Topic papers in Appendix B of the original version of this chapter were relocated to Appendix B of Chapter 1.

On January 15, 1991, the staff issued its DSER for Chapter 6 of the Evolutionary Requirements Document. On April 9, 1991, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 6, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 6, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 6 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 6

Chapter 6 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for building design and arrangement.

The key topics addressed in the Chapter 6 review include EPRI-proposed design requirements for

- human factors
- optimization of plant volume
- architecture
- standardization

- structural design basis
- plant life
- site envelope
- design process

1.3 Policy Issues

During its review of Chapter 6 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 6 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) human factors considerations (2.1 and 4.6.5)

(2) structural steel members' growth due to fire and design-basis loss-of-coolant accident (2.1)

(3) inspections of potential structural degradation of safety-related structures (2.1)

(4) standard embedment depth (2.1 and 3.3.2)

(5) qualification of analytical techniques for structural and mechanical design (2.1)

(6) stiffness degradation of modular concrete structures (2.1)

(7) anchorage design and installation of safety-related tanks (2.1)

(8) steel containment corrosion, spent fuel pool leakage, and degradation of intake structures (2.1)

(9) reliability and structural strength of modularly constructed components (2.2)

(10) location of oil-filled transformers (2.3)

(11) computer codes for evaluating shielding design (2.4)

(12) use of American National Standards Institute/American Nuclear Society (ANSI/ANS) 2.8-1981 to determine the probable maximum precipitation and probable maximum flood (3.3.1 and 3.3.2)

(13) design requirements for outdoor tanks containing liquid radioactive material (3.3.10)

(14) modification of the requirements for the design of instrument impulse lines (4.2.4)

(15) inservice inspection considerations (4.2.7)

(16) use of the containment air volume to dilute the containment hydrogen concentration to less than 13 percent as the sole means of postaccident combustible gas control (4.3.2)

(17) core debris coolability and cavity sizing criteria (4.3.2)

(18) movement of fuel (4.3.3)

(19) containment design leak rate of 0.5 percent per day (4.3.4)

(20) location of the control complex (4.6.5)

(21) exclusion of computer room, which is part of the "control room emergency zone," from "control room envelope" (4.6.5)

Confirmatory Issues

(1) design criteria for fire exits (2.3)

(2) fire barriers between the control room and peripheral rooms (2.3)

(3) clarification of the discussion of the general security requirements related to building design and arrangement (2.3)

(4) level of embedment for PWR containment building (3.3.2)

(5) alternative seismic restraints (4.2.3)

(6) vertical separation requirements for cable trays (4.2.6)

(7) compliance with Institute of Electrical and Electronics Engineers 384 (4.2.6)

(8) use of lightweight conduit, fittings, and cable tray materials (4.2.6)

(9) assigning of aisles and corridors to the safety trains (4.2.6)

(10) use of ANSI N101.4-1972 for coatings (4.2.10)

(11) addition of the commitment to meet ANSI N101.4-1972 for qualification of coatings (4.3.2)

The final disposition of each of these issues is discussed in greater detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All issues identified in the DSER for Chapter 6 of the Evolutionary Requirements Document have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.6.V-1 thermal growth of steel members (2.1)

E.6.V-2 inspectability of structural walls (2.1)

E.6.V-3 deviations from National Fire Protection Association codes and standards (2.3)

E.6.V-4 qualification criteria for fire barriers (2.3)

E.6.V-5 fire protection features in the heating, ventilation, and air conditioning (HVAC) design criteria (2.3)

E.6.V-6 compliance with the requirements of Three Mile Island (TMI) Action Plan Item II.B.2 (2.3)

E.6.V-7 details of shielding design and shielding computer codes (2.3, 2.4, and 4.2.8)

E.6.V-8 effect of site-specific topography on standard overall site arrangement (3.1)

E.6.V-9 flooding protection design requirements (3.3.1)

E.6.V-10 alternative seismic restraint devices (4.2.3)

E.6.V-11 piping and instrument line support design (4.2.4)

E.6.V-12 description of airborne radioactive material sources (4.2.5)

E.6.V-13 potential high-radiation areas, shielding, and measures for minimizing exposure (4.2.8 and 4.2.9)

E.6.V-14 review of coatings against SRP Section 6.1.2 (4.2.10 and 4.3.2)

E.6.V-15 use of epoxy-coated reinforcing bars at intake structures (4.2.11)

E.6.V-16 features to ensure H2 concentrations do not exceed detenation levels (4.3.2)

E.6-V-17 elimination of diagonal rebar in reinforced-concrete containment (4.3.2)

E.6-V-18 floor size for reactor vessel cavity/drywell (4.3.2)

E.6-V-19 design features that preclude potentially lethal radiation levels (4.3.3)

E.6.V-20 containment access control (4.3.3 and 4.3.4)

E.6.V-21 details of design of BWR reactor building (4.4.2)

E.6.V-22 details of design of PWR auxiliary building (4.4.3)

E.6.V-23 turbine-generator building seismic design loading (4.5.2)

E.6.V.24 details of design of BWR turbine-generator building (4.5.4)

E.6.V-25 details of design of radwaste facility (4.6.3)

E.6.V-26 details of emergency onsite power supply facility (4.6.4)

E.6.V-27 details of HVAC design for control complex (4.6.5)

E.6.V-28 details of design of technical support center (4.6.6)

2 KEY REQUIREMENTS

2.1 General Design Requirements and Policy Statements

Section 1 of Chapter 6 of the Evolutionary Requirements Document contains those policies established by the ALWR Utility Steering Committee relating to constructibility, operability, maintainability, sabotage, and standardization as they relate to building design and arrangement. The following is a summary of these policies:

- With regard to the arrangement of buildings, emphasis is to be placed on improved constructibility through material selection, component standardization, and space layout to minimize interferences and improve accessibility.

- Operability and maintainability are to be improved through activities that emphasize accessibility in the design, including the use of early periodic design reviews and the separation of potentially contaminated spaces from noncontaminated spaces.

  EPRI states that improvements in operation and maintenance are expected to be accomplished by providing space for access to operate and maintain components (space requirements will be determined by performing maintenance reviews at early design stages), and by separating potentially contaminated areas from noncontaminated areas. Historically, plant maintenance has accounted for most of the occupational dose at light-water reactors. Increasing accessibility to components located in radiological control areas (RCAs) will facilitate maintenance operations on these components, will decrease the maintenance time spent in the RCA, and will result in overall lower occupational doses.

- Vulnerability to sabotage is to be minimized through the physical separation of engineered safety systems, access control, and implementation of the physical security provisions as described in Chapter 9 of the Evolutionary Requirements Document.

- The standardization objectives outlined in Chapter 1 of the Evolutionary Requirements Document are to be implemented through the use of a standard power generation complex and a reference site arrangement as described in Chapter 6 of the Evolutionary Requirements Document.

Section 2.1 of Chapter 6 identifies the general design requirements related to (1) human factors, (2) space and volume optimization, (3) architecture and appearance, (4) standardization, (5) structural design bases, (6) plant life, (7) site envelope, and (8) the design process.

Human Factors Considerations

In its letter of August 30, 1990, the staff requested that EPRI provide additional information on the requirements and acceptance criteria for human factors considerations to ensure that operability and maintainability are achieved in building arrangements. The staff also requested that EPRI provide information on the scope and objectives of EPRI NP-4350, "Human Engineering Guidelines for Maintainability," which was referenced in Section 2.1.1 of

Chapter 6 of the Evolutionary Requirements Document. In the DSER for Chapter 6, the staff concluded that the need for additional information on the requirements and acceptance criteria for human factors considerations and on the scope and objectives of EPRI NP-4350 should be considered open issues. The staff's evaluation of human factors considerations is provided in Chapter 10 of this report. Therefore, this DSER open issue is closed.

Equipment Accessibility

Section 2.1.1.2 of Chapter 6 states that equipment located in normally inaccessible areas (including areas where the dose rate exceeds 100 mrem/hour) will be limited to those items that do not require surveillance testing during operation, that are extremely reliable, or that will not impair plant availability if they fail. This limitation ensures the accessibility of equipment that may require frequent maintenance or surveillance and is acceptable.

Thermal Growth of Structural Steel Members

Section 2.1.5.2 of Chapter 6 states that appropriate and achievable construction tolerances will be provided for dimensions, locations, and clearances for all structural systems and components. The tolerances will be included in installation specifications and on drawings. In many old plant designs, because growth of structural steel members due to fire and the design-basis loss-of-coolant accident (LOCA) was not considered, expensive modifications had to be made. In the DSER for Chapter 6, the staff recommended that EPRI address this particular design consideration and identified this as an open issue.

EPRI has revised Section 2.1.5.2 of Chapter 6 to reference the requirements of Sections 4.5.5.1.5 and 4.5.5.6 of Chapter 1. The staff has reviewed the requirements in Section 4.5.5.6.2 of Chapter 1 and concludes that they adequately address this open issue with respect to in-plant fire hazards. However, the design requirements in Section 4.5.5.6 of Chapter 1 alone are not adequate to ensure that thermal growth of structural steel members due to pipe rupture has been considered to achieve appropriate tolerances, locations, and clearances for structural systems and components. Accordingly, unless it can be shown that the effects of in-plant fires envelope the effect of LOCAs, the staff will review individual applications for FDA/DC to ensure that designers consider the effects of thermal growth of structural steel members due to LOCAs and fires. Therefore, this DSER open issue is closed.

Inspectability

In the DSER for Chapter 6, the staff recommended that all safety-related structures, both steel and concrete, be arranged in configurations that permit accessibility for inspections of potential structural degradation. This should include providing adequate physical space for inspection and surveillance as well as a reliable means for assessing potential degradation of structures where direct inspections are precluded (e.g., where filler material is placed between the containment and the adjacent concrete structure). This was identified as an open issue in the DSER.

EPRI has revised Section 4.2.11.1.2 of Chapter 6 to require a common basemat for the power generation complex (PGC) structures including the control, auxiliary, and containment buildings, that permits access to both sides of all interior structural walls. For PWR plants, Sections 4.3.4.1.1 and 4.3.4.1.2 were added to Chapter 6 and specifically require access to the outside and inside of the steel shell containment for inspection. The staff concludes that these requirements are acceptable to address the open issue for all structural walls within the common basemat and for those portions of exterior walls along the edge of the common basemat that are not immediately adjacent to another building. They are not acceptable, however, to address the issue for exterior walls along the edge of the common basemat that are immediately adjacent to the exterior walls of another building supported on a separate foundation (e.g., between the exterior walls of the control and turbine building). The staff will review individual applications for FDA/DC to ensure that plant designers who propose to place a building with a separate foundation adjacent to the common mat describe their proposed methods for inspecting the structural degradation between the two foundations. Therefore, this DSER open issue is closed.

Standard Embedment Depth

Section 2.1.7 of Chapter 6 specifies a depth of 25 to 30 feet below the average site grade level for the founding materials with the properties stated Section 2 of Chapter 1. In the DSER for Chapter 6, the staff stated that additional justification was needed to establish the significance of requiring a 25- to 30-foot standard embedment depth and recommended that EPRI provide a discussion of how the plant designer will address the adequacy of a shallow soil site founded on bed rock, which is more competent than the material defined in Table 1.2-6 of Chapter 1. This was identified as an open issue in the DSER.

In a letter dated November 18, 1991, EPRI stated that, by definition, standard plants will have a standard embedment. The standard embedment of 25 to 30 feet for nuclear island structures was originally specified to achieve an appropriate bearing capacity at most soil sites. Where sites have competent rock at shallower depths, the rock will be excavated to the depth that accommodates the standard plant arrangement to permit major access openings at grade level. The staff concludes that EPRI's position is acceptable.

In a letter dated July 2, 1991, responding to the concerns (selection of backfill material, location of seismic input, and soil dynamic properties for soil-structure interaction analysis) pertaining to engineering backfill to achieve 25- to 30-foot embedment, EPRI stated that it is the responsibility of the plant designer to establish these parameters under the guidance in SRP Sections 3.7.1 ("Seismic Design Parameters"), 3.7.2 ("Seismic System Analysis"), and 3.7.3 ("Seismic Subsystem Analysis"), with which the ALWR program is committed to comply. The staff concludes that EPRI's response is acceptable and will review the adequacy of the engineering backfill on a plant-specific basis. Therefore, this DSER open issue is closed.

Analytical Techniques

Section 2.1.8.1 of Chapter 6 requires the use of "proven and verified" computer programs for design process analyses. In the DSER for Chapter 6, the staff requested that EPRI clarify the criterion "proven and verified" and the qualification criteria and the basis thereof. This was identified as an open issue. In a letter dated November 18, 1991, EPRI stated that its position is to use American National Standards Institute (ANSI) 10.4 (1987) as the guidance for verifying and validating computer programs and that this standard will be referenced in Table 1.4-2, Chapter 1. Although ANSI 10.4 (1987) has been included in the list of industry technical standards in Table 1.4-2 of Chapter 1, the staff has not completed its review of this standard for consistency with regulatory positions. Plant designers intending to use this standard should submit a request for its approval by the NRC staff on a case-by-case basis. Therefore, this DSER open issue is closed.

Stiffness of Modularly Constructed Concrete Structures

Shear wall tests at Los Alamos National Laboratory have indicated that stiffness degrades under repeated loads. This stiffness degradation also exists in modularly constructed concrete structures. Also, damping of modular concrete structures may result in characteristics different from those of conventionally constructed concrete structures. In the DSER for Chapter 6, the staff recommended that EPRI address stiffness degradation under repeated loads in modularly constructed concrete structures and the differences between modularly and conventionally constructed concrete structures. The staff also recommended that EPRI address the effects of these differences on structural integrity and piping and equipment design. This was identified as an open issue in the DSER.

In a letter dated November 18, 1991, EPRI stated that safety-related concrete structures in ALWR plants will be constructed primarily of monolithic concrete similar to past practice because experience has shown that this type of construction is more cost effective than making modules out of precast concrete. Also modular construction will be more in the form of equipment modules including piping and electrical systems supported by a structural steel framework attached to the primary building at connection points, which is the same as current common practice. EPRI stated that, for this reason, the seismic response of modules will not be substantially different from that in current plants and, hence a justification for differences in stiffness was unwarranted. The staff agrees and concludes that EPRI's position is adequate to address the issue of differences between modularly and conventionally constructed concrete structures. Therefore, this DSER open issue is closed.

Anchorage of Safety-Related Tanks

The Maine Yankee Seismic Margin Study and the resolution of Unresolved Safety Issue A-46, "Seismic Qualifications of Equipment," have indicated that the anchorage of the safety-related tanks was a weakness at operating plants. In the DSER for Chapter 6, the staff recommended that EPRI emphasize tank anchorage design and installation in the Evolutionary Requirements Document and identified this as an open issue.

Section 12.6.2 of Chapter 1 requires that anchor bolts for flat-bottom tanks be extended at least 2 feet above the concrete foundation level and that the anchor bolt chairs be extended full height and continuously welded to the tank wall. These requirements are intended to distribute seismic forces and to develop ductility. The staff concludes that these requirements acceptably address this issue. Therefore, this DSER open issue is closed.

Corrosion and Leakage

In the DSER for Chapter 6, the staff recommended that EPRI thoroughly assess the potential for steel containment corrosion, spent fuel pool leakage, and degradation of intake structures, and reflect the assessment in the Evolutionary Requirements Document. Because Section 4.3.4.1.1 of Chapter 6 requires the inclusion of appropriate corrosion allowance in the design of steel shell containments and Section 2.3.1.1.6 of Chapter 7 requires that a leak chase system be installed to collect any potential leakage behind the weld seams of the spent fuel pool liner plate, the staff concludes that EPRI has provided requirements that adequately address these concerns. Therefore, this DSER open issue is closed.

Conclusion

The staff concludes that the requirements in Section 2.1 of Chapter 6 of the Evolutionary Requirements Document are consistent with regulatory criteria and are, therefore, acceptable.

2.2 Design for Construction

Section 2.2 of Chapter 6 of the Evolutionary Requirements Document identifies the key requirements necessary to ensure that plant construction is consistent with operational and maintainability goals. Such key requirements include: (1) construction sequence, (2) segregation of safety-related and non-safety-related construction areas, (3) modularization, and (4) startup testing.

Preliminary construction schedules are provided by EPRI in Appendices B (BWR) and C (PWR) of Chapter 6 of the Evolutionary Requirements Document. EPRI emphasizes the physical separation of safety-related and non-safety-related areas to minimize construction costs in non-safety-related areas. EPRI requires that the plant design permit preassembly and installation of large modules in plant construction and that the plant design include features that permit construction startup testing to be integrated with preoperational testing.

The staff was concerned about the widespread use of modular construction being proposed throughout the Evolutionary Requirements Document. In the DSER for Chapter 6, it recommended that EPRI provide the staff with an analysis demonstrating that the same degree of structural strength and reliability provided in conventional nuclear power plant construction will be maintained with the modularization scheme proposed in the Evolutionary Requirements Document. This was identified as an open issue in the DSER.

In a letter dated November 11, 1991, EPRI stated that any unusual structural modules that could perform other than as an integral or composite part of the structure will require justification on a plant-specific basis. The staff concludes that EPRI's position is acceptable and will review individual applications for FDA/DC to evaluate the proposed use of any unusual structural modules (if any) by the plant designer. Therefore, this DSER open issue is closed.

The staff concludes that the requirements in Section 2.2 of Chapter 6 are consistent with SRP criteria and are, therefore, acceptable.

2.3 Design for Safety

Section 2.3 of Chapter 6 of the Evolutionary Requirements Document identifies the key requirements necessary to ensure that safety considerations are integrated into building design along with operational, maintenance, and construction schedule needs. EPRI places emphasis on using plant structures to the extent practicable for access control and radiation shielding and on avoiding the routing of non-safety-related piping and ducting in the vicinity of safety-related equipment.

Fire Protection

Section 2.3.3 of Chapter 6 specifies the following requirements for passive fire protection features:

- Construction materials in buildings will conform to the requirements of SRP Section 9.5.1, "Fire Protection Program."
- Cooling towers will be constructed of noncombustible materials.
- Design of openings through fire barriers will conform to SRP Section 9.5.1.
- Rooms for computers that are not part of the control room complex and that perform safety-related functions will be separated from other areas of the plant and from their redundant backups by barriers with a minimum fire resistance rating of 3 hours.
- Switchgear rooms containing safety-related equipment will be separated from the remainder of the plant by 3-hour-fire barriers, redundant switchgear safety divisions will be separated from one another by 3-hour-fire barriers, and equipment in switchgear rooms will be accessible, to the extent practicable, on all sides for manual fire suppression.
- Redundant safety-related panels remote from the control room complex will be separated from each other by barriers with a minimum fire resistance rating of 3 hours, and panels that provide remote shutdown capabilities will be separated from the control room complex by 3-hour-fire barriers.
- Safety-related battery rooms will be separated from each other and from other areas of the plant by 3-hour-fire barriers, and dc switchgear and converters will not be located in the battery rooms.
- Exterior walls of safety-related buildings that may be exposed to fire hazards will be designed as 3-hour-fire barriers, and the openings and penetrations will be sealed with materials having a 3-hour-fire rating.
- Outdoor oil-filled transformers will have features for confining oil spill and water deluge or they will drain away from buildings. Such transformers will be located at least 50 feet from buildings. Exterior building walls located in the vicinity of transformers will have a 3-hour-fire rating, and openings in the wall will be avoided.

- Diesel fuel oil storage areas (except day tanks) will not be located inside buildings containing safety-related equipment. Tanks wi[illegible] be totally buried or located above ground at least 50 feet from any building containing safety-related equipment or will be housed in a separate building with a 3-hour-fire rating.

- Personnel access and escape routes will be provided for each fire area. Fire exit routes will be clearly marked. Stairwells outside the primary containment serving as escape routes, access routes for firefighting, or access routes to safe-shutdown equipment will be enclosed in masonry or concrete towers, with a minimum 2-hour-fire rating, and self-closing Class B fire doors and will be provided with sufficient emergency lighting. Stairwell design will conform to Chapters 6 and 7 of National Fire Protection Association (NFPA) 803. Fire exits will be provided in accordance with the requirements of Chapter 5 of NFPA 101.

- Floor drains sized to remove water used for firefighting so that safety-related equipment is not flooded will be provided in those areas where fixed water fire suppression systems are installed. Floor drains will also be provided in other areas where hand hoses may be used, if such water supply could cause unacceptable damage to safety-related equipment. Where gas fire suppression systems are installed, drains will be provided with adequate seals or the suppression system will be sized to compensate for the loss of the suppression agent through the drains. Drains in areas containing combustible liquids will have provisions for preventing the backflow of combustible liquids into safety-related areas through the interconnected drain systems.

- The control complex will be separated from the remainder of the plant by 3-hour-fire barriers at walls, ceiling, and floor. Peripheral rooms in the control complex will be separated from the control room by noncombustible construction with a fire resistance rating of 1 hour.

The staff evaluated the criteria for the fire protection system in the Evolutionary Requirements Document against the criteria of SRP Section 9.5.1 (Branch Technical Position CMEB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants," July 1981) and supplemental guidance issued by the Commission. Three examples of such supplemental guidance are (1) Generic Letter 81-12, which contains information on safe-shutdown methodology; (2) Generic Letter 86-10, which contains important technical information, such as that pertaining to conformance with NFPA codes and standards; and (3) the Commission's Staff Requirements Memorandum on SECY-90-016 dated July 26, 1990. The staff discusses the criteria and the basis for their use in Section 2.5 of Chapter 5 and Section 3 of Chapter 9 of this report. The staff's evaluation of the fire performance requirements in Chapter 6 of the Evolutionary Requirements Document follows.

EPRI has generally followed NRC's concept of defense-in-depth with regard to fire protection. The three steps of defense-in-depth and EPRI's implementation of these steps follow:

(1) Reduce the possibility of fire starting in the plant - EPRI specifies that fire-resistant and fire-retardant materials will be used in the design of reactor plants referencing the Evolutionary Requirements Document to minimize and isolate fire hazards. Either low-voltage or

fiberoptic multiplexed circuits will be used in ALWR designs, thus eliminating the need for cable spreading rooms and substantially reducing the amount of combustible cable insulation and higher voltage ignition sources in the control room.

(2) Detect and suppress a fire promptly - EPRI specifies that automatic detection and a suitable mix of automatic and manual fire suppression capability will be incorporated into ALWR designs.

(3) Ensure that any fire that might occur will not prevent safe shutdown of the plant even if fire detection and suppression efforts should fail - EPRI has attempted to ensure this in the Evolutionary Requirements Document. A detailed evaluation of the effectiveness of this approach follows.

The fire protection program described by EPRI is intended to protect safe-shutdown capability, prevent the release of radioactive materials, minimize property damage, and protect personnel from injury as a result of fire.

EPRI considered not only the three aspects of defense-in-depth outlined above, but also such features of general plant arrangement as

- access and egress routes
- equipment locations
- structural design features that separate or isolate redundant safety-related systems
- floor drains
- ventilation
- construction materials

EPRI specifies that applicable NFPA codes and standards will be incorporated in the design and layout of an ALWR facility. An ALWR designer or applicant will be required to identify any deviations from these codes and standards and to describe in the fire hazards analysis for a plant-specific design the deviations and measures taken to ensure that equivalent protection is provided.

In the DSER for Chapter 6, the staff stated that in its October 19, 1989, response to the staff's request for additional information dated June 8, 1989, EPRI had committed to change Chapter 9 of the Evolutionary Requirements Document to refer to SRP Section 9.5.1, Revision 1 of Generic Letter 81-12, and Generic Letter 86-10 rather than NFPA 803.

EPRI has changed the fire protection requirements to comply with the SRP rather than NFPA 803. Sections 2.3.3.2 and 2.3.3.4 of Chapter 6 have been revised to state that construction materials in buildings and the design of openings through fire barriers will conform to the guidelines of SRP Section 9.5.1. EPRI states that the requirements will reduce the toxic and corrosive gases resulting from fire and limit flame spread, smoke, and the amount of fuel present in the buildings. Because the revised requirements meet the SRP guidelines, the staff concludes that they are acceptable. In addition, the staff will review applications for FDA/DC to ensure that they have also addressed the guidance in Generic Letter 81-12, Revision 1, and Generic Letter 86-10.

Fire Barrier Design

In its letter of June 8, 1989, the staff stated that it was concerned about the qualification criteria for fire barriers, including the capability of fire doors, fire dampers, and fire barrier penetration seals to withstand the effects of fire and fire suppressants.

In its letter of October 19, 1989, EPRI stated its intention to conform to the fire barrier qualification guidance in SRP Section 9.5.1. EPRI's commitment to comply with SRP Section 9.5.1 is acceptable, and the issue is closed. However, because the actual details of the fire barrier design are outside the scope of the Evolutionary Requirements Document, the staff will evaluate the design and the installation of all components of fire barriers during its review of an individual application for FDA/DC (during the plant-specific licensing process).

Oil-Filled Transformers

In its letter of June 8, 1989, the staff stated that it was concerned that oil-filled transformers could be located less than 50 feet from exterior building walls.

In its letter of October 19, 1989, EPRI responded, in effect, that a specific plant design might dictate locating oil-filled transformers less than 50 feet from exterior building walls, even though there are now no known instances where that would be true.

In the DSER for Chapter 6, the staff concluded that EPRI's response was not acceptable and that EPRI should provide a commitment that no oil-filled transformers will be located less than 50 feet from exterior building walls. This was identified as an open issue.

EPRI has revised Section 2.3.3.11 of Chapter 6 to require that outdoor oil-filled transformers have oil spill and water deluge confinement features or drainage away from the buildings. Such transformers must be located at least 50 feet from buildings. Where oil-filled transformers are located within 50 feet of buildings, the exterior walls in the vicinity of the transformers will have a fire resistance rating of at least 3 hours and wall openings will be avoided. The drainage system will confine or direct potentially flaming oil from a transformer fire so that other electric power supply circuits will not be affected.

EPRI now requires oil-filled transformers to be located at least 50 feet from buildings and also requires a noncombustible and heat-resistant wall design to minimize the effect of spill fires and explosions involving outdoor oil-filled transformers located less than 50 feet from the wall. These requirements help ensure that shared buildings will retain their capability to perform their intended safety functions in the event of a transformer fire. The staff concludes that the fire protection features in the Evolutionary Requirements Document meet Section 5.a.(13) of SRP Section 9.5.1, Branch Technical Position CMEB 9.5-1, and are acceptable. Therefore, this DSER open issue is closed.

Fire Exits

In the DSER for Chapter 6, the staff stated that EPRI had committed to revise the requirements for the design of fire exits for personnel egress to comply with Chapter 5 of NFPA 101, "Life Safety Code." This was identified as a confirmatory issue.

The staff has verified that Section 2.3.3.13 of Chapter 6 has been revised to require that fire exits be provided in accordance with Chapter 5 of NFPA 101 and that the stairwell design meet Chapters 6 and 7 of NFPA 803. These revisions meet the staff guidelines and are acceptable. Therefore, this DSER confirmatory issue is closed.

Heating, Ventilation, and Air Conditioning (HVAC) Design

In its letter of June 8, 1989, the staff requested that EPRI identify the fire protection features that will be provided for HVAC systems. The staff's specific interest centered on automatic fire detection and suppression systems internal to the system and on interlocks between the fire protection systems and the fan motor controls.

In its letter of October 19, 1989, EPRI stated that the requirements for fire protection of the HVAC system in SRP Section 9.5.1 will be followed. The staff concludes that the EPRI response is acceptable. However, it will review in detail the design and installation of the entire HVAC system during its licensing review of an individual application for FDA/DC to ensure adequate fire protection has been provided.

Additional guidance in this area is also provided in ANSI/American Nuclear Society (ANS) 59.2-1985, "Safety Criteria for HVAC Systems Located Outside Primary Containment." (ANS is planning minor revisions to update this standard.)

itions Inside the Control Complex

In the DSER for Chapter 6, the staff stated that in a letter dated October 19, 1989, EPRI had committed to revise the appropriate section of Chapter 6 to require that peripheral rooms in the control room complex be separated from the control room by noncombustible structure with a fire resistance rating of 1 hour. This was identified as a confirmatory issue.

The staff has verified that Section 2.3.3.15 of Chapter 6 has been revised to state that the control room complex will be separated from the remainder of the plant by barriers at the walls, ceiling, and floor with a minimum fire resistance rating of 3 hours. Peripheral rooms in the control room complex will be separated from the control room by noncombustible construction with a fire resistance rating of 1 hour. The fire protection requirements for the peripheral rooms in the control room complex meet the staff guidelines and are acceptable. Therefore, this DSER confirmatory issue is closed.

Postaccident Access

Section 2.3.4 of Chapter 6 of the Evolutionary Requirements Document requires that the plant designer prepare a plan for postaccident access for surveillance and recovery operations and that, in accordance with the TMI Action Plan (NUREG-0737) requirements, the plant arrangement include provisions for postaccident access for these operations. The plan to be prepared by the plant designer, as required by EPRI, will identify areas requiring postaccident access. These areas must be shielded so that required operations in these areas are not adversely affected by postaccident radiation levels. The systems designed to function after an accident may include, but are not limited to, the containment system, the residual heat removal system, the core spray system, the reactor core isolation cooling system, the postaccident sampling system, and the standby gas treatment system. Vital areas that may require personnel access after an accident include the control room and technical support center (continuous occupancy), the remote shutdown panel (frequent occupancy), and the sampling station and sample analysis area (infrequent occupancy). Each applicant for FDA/DC must perform a design review of the plant shielding to ensure that the plant's vital areas are accessible after an accident in accordance with the criteria of TMI Action Plan Item II.B.2 (NUREG-0737).

It is outside the scope of the Evolutionary Requirements Document to fully describe the shielding design requirements that allow access to the plant's vital areas following an accident. However, EPRI has revised Appendix B to Chapter 1 and committed to comply with the shielding criteria of TMI Action Plan Item II.B.2, as required by 10 CFR 50.34(f)(2)(vii). The staff concludes that this is acceptable and will verify compliance during its review of an individual application for FDA/DC.

Security Requirements

Section 2.3.5 of Chapter 6 specifies the general security requirements related to building design and arrangement. EPRI states that the design will (1) minimize the security and radiological control points to the extent practicable, (2) enhance the capability to resist radiological sabotage, and (3) not hinder necessary operator access during emergencies.

Section 2.3.5.1 of Chapter 6 requires the plant designer to evaluate access to vital and protected areas during plant construction, normal operation, refueling operations, and outages. (Section 5.2.4.2 of Chapter 9 of the Evolutionary Requirements Document also requires an evaluation of the effect of security systems on plant operations, maintenance, and testing.) Section 2.3.5.2 of Chapter 6 requires that building exteriors be arranged to avoid irregular shapes to minimize the burden of complying with security requirements. Section 2.3.5.3 requires the plant designer to define emergency paths from the control room to the remote shutdown panel(s), the technical support center, and the onsite emergency power supply. It also specifies that operator emergency access should not be blocked because of security system failures. Because EPRI committed to make some minor changes to clarify Section 2.3.5, the staff identified clarification of the discussion of the general security requirements related to building design and arrangement as a confirmatory issue in the DSER for Chapter 6. The staff has confirmed that these changes were made in Revision 1 to Chapter 6. Therefore, this confirmatory issue is closed.

However, the requirement resulting from the clarification of Section 2.3.5.4 had the potential for delaying operator emergency access to vital equipment and appeared to be minimally beneficial with regard to protection against insider sabotage.

Section 2.3.5.4 of Chapter 6 specifies that, to the extent practicable, plant arrangement and building design features will be used to help protect against insider sabotage. The rationale portion of this section states that this requirement, coupled with appropriate administrative procedures, will eliminate the possibility that a badged individual can reach and enter all divisions of safety equipment within a short time. In its June 24, 1991, letter, EPRI committed to change Chapter 6, Sections 1.5.2 and 2.3.5, and Chapter 9, Section 5.2.4.1, to require security controls access to vital areas only at vital area boundaries and not between redundant divisions of vital components. The staff has confirmed that these changes have been made and resolve its concerns about the possibility that the security system might interfere with safe plant operation. Protection against insider sabotage still will be provided by vital area access controls. Additional protection against insider sabotage may result from the vulnerability analysis required in Chapter 9. Further protection against insider sabotage will be provided by access authorization and fitness-for-duty programs required by 10 CFR Parts 73 and 26.

In response to the staff comments, EPRI revised Section 2.3.5.5 of Chapter 6 to consolidate the requirements dealing with vital areas and barriers for vital safety equipment in Chapter 9 of the Evolutionary Requirements Document rather than in Chapter 6.

Internal Flooding Requirements

Section 2.3.6 of Chapter 6 specifies the following requirements related to internal flooding:

- Plant arrangements will be such that large leaks in one division of a safety-related system will not cause flooding in the areas housing equipment from another division of the same system or from another safety-related system of another division.

- Compartments subject to flooding or pressurization as a result of an accident or equipment failure will be identified, and design criteria will be established to maintain the structural integrity of the compartment.

- Potential breaks of non-safety related systems, such as the circulating water or service water systems shall be considered in locating electrical equipment in the auxiliary, control, or turbine buildings.

- Cubicles containing radioactive tanks will be designed to retain the contents of the largest tank in the cubicle in order to prevent the spread of radioactive fluid in the event of a tank rupture.

The staff concludes that the design requirements in Section 2.3.6 of Chapter 6 for protection against internal flooding are consistent with the guidance in SRP Section 3.4.1, "Flood Protection," and are, therefore, consistent with the guidance of Regulatory Guide 8.8, "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable." They are, therefore, acceptable.

Severe-Accident Considerations

Severe-accident considerations supplementing those of Chapter 5 of the Evolutionary Requirements Document are contained in Sections 2.3.7 and 4.3 of Chapter 6 and are discussed by the staff in Section 4 of this SER chapter. The staff's evaluation of EPRI's severe-accident considerations is provided in Chapter 5 of this report.

Protection From External Threats

Requirements for the analysis of man-made hazards and of natural phenomena are given in Chapter 1 of the Evolutionary Requirements Document. The staff's evaluation of EPRI's requirements related to protection against flooding from external causes is provided in Chapter 1 of this report. The discussion of protection against sabotage in Section 2.3.8 of Chapter 6 of the Evolutionary Requirements Document is taken by the staff to mean only that sabotage need not be included in site-specific probabilistic risk analyses. The requirement for analyses by the plant designer to determine if any plant design features are warranted for protection against sabotage in addition to those specified in Chapters 5 and 6 is established in Chapter 9 of the Evolutionary Requirements Document. In addition, acceptable site-unique security and contingency plans required by 10 CFR 50.34 will need to be included in a combined license application.

Toxic Material and Combustible Gases

Section 2.3.9 of Chapter 6 specifies that toxic materials will be stored at least 50 feet from the control room or intake to the compressor of the breathing air system. This will minimize the potential for contaminating the control room atmosphere or respirator breathing air supply in the event of a leak of toxic gas from a tank or from the bottled gas storage area. In addition, stored containers of combustible gases will be buried or located above ground at least 50 feet from any building containing safety-related equipment. The effects of fire, equipment failure, fuel handling accidents, meteorological conditions, topography, and locations of personnel will be considered when determining the location of gas containers.

Conclusion

The staff has evaluated the requirements of Section 2.3 of Chapter 6 against the criteria of the SRP. Although the requirements of Section 2.3 do not conflict with current regulatory requirements and are acceptable, they do not envelop all regulatory criteria. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the appropriate SRP criteria, or provide justification for alternative means of implementing the associated regulatory requirements.

2.4 Design for Operation and Maintenance

Section 2.4 of Chapter 6 specifies the building requirements intended to ensure that an ALWR design meeting the criteria of the Evolutionary Requirements Document will have improved access, hoisting and lifting features, support systems, and weather protection and radiological protection features to facilitate maintenance and operation activities. Included in this section are requirements that the plant designer perform a maintainability evaluation, provide minimum aisleway dimensions, provide aligned hatchways to facilitate vertical lifts through multiple levels, provide staging areas, provide freight and personnel elevators and stairways on the basis of the maintainability evaluation, perform a shielding cost-benefit study, and analyze equipment and personnel movement routes.

Section 2.4.1 of Chapter 6 requires that the plant designer develop a maintainability evaluation that will identify limiting tasks that control the sizes of aisleways, hatches, and lifting devices at the time the plant's general arrangement drawings are being developed. This maintainability evaluation will be used to identify needed work spaces and clearances; the adequacy of platforms and ladders; lifting and pulling points in walls, ceilings, and floors; and access routes to be followed. Aisleways will be sized to provide unobstructed pathways for the removal or installation of all planned components (except in-building large tanks). Provisions for lifting and handling major equipment and components weighing more than 50 pounds will be provided in the form of cranes, monorail hoists, and rigging attachment points. All equipment requiring periodic access for operation, maintenance, or inspection will be provided with access stairs and work platforms. To minimize radiation exposure levels to plant operating personnel, the plant designer will include features in the design of the plant to facilitate the use of robots for plant maintenance activities. These features, implemented as a result of the maintainability evaluation described above, are intended by EPRI to facilitate access during maintenance, operations, and inspection activities. If properly implemented, these features will help reduce occupational exposures and are in compliance with the guidelines of Regulatory Guide 8.8. Several of these design features (such as the capability to remove all major plant components, except the reactor vessel and some large tanks) will also facilitate eventual plant decommissioning operations.

The objective of the plant's radiation shielding is to provide protection against radiation for operating personnel, both inside and outside the plant, during normal operation, including anticipated operational occurrences, and during reactor accidents. Section 2.4.4 of Chapter 6 indicates that the plant and building arrangement will be designed to minimize personnel exposure to radiation and contamination by optimizing shielding and equipment maintenance design features. EPRI states that source terms used for shielding design will be based on NRC regulations and existing plant surveys and will take into account any reactor coolant water additives. In the DSER for Chapter 6, the staff identified the lack of a list of acceptable shielding design computer codes in the Evolutionary Requirements Document as an open issue. EPRI has revised Appendix B to Chapter 1 and has committed to meet SRP Sections 12.3 and 12.4, "Radiation Protection Design Features," which address this issue. Since it is outside the scope of the Evolutionary Requirements Document to list specific shielding design computer codes, the staff concludes that EPRI's response is acceptable. Therefore, this DSER open issue is closed. The plant designer, however, should identify all such shielding codes planned for use in shielding design.

Because Chapter 6 of the Evolutionary Requirements Document does not fully describe shielding design requirements that are consistent with SRP Sections 12.3 and 12.4, the staff will ensure that the ALWR designer or applicant complies with this guidance. The ALWR designer or applicant will be required to provide a description of radiation sources, during normal operations and accident conditions in the plant, that will be used as the basis for designing the radiation protection program and for shield design calculations. This description should include isotopic composition, location in the plant, source strength and source geometry, and the basis for the values.

The Evolutionary Requirements Document invokes higher initial construction costs, which are expected to be recovered throu h improved maintainability, reduced occupational radiation exposure, and reduced equipment outages. Because the requirements of Section 2.4 of Chapter 6 are primarily of a non-safety nature, they are not subject to regulatory review criteria. However, for those items that are subject to regulatory review criteria, with the exceptions noted above, the staff concludes that the design requirements in Section 2.4 of Chapter 6 are consistent with staff guidance and are, therefore, acceptable.

3 OVERALL SITE ARRANGEMENTS

3.1 Introduction

Section 3 of Chapter 6 of the Evolutionary Requirements Document contains requirements for the arrangement of facilities on the plant site. The facilities include the

- power generation complex
- radiological access control points
- electrical switchyard
- emergency operating facility
- treatment and conditioning facilities
- tanks and storage facilities
- transport facilities
- cooling water facilities
- towers/stacks
- utilities
- miscellaneous site facilities
- construction facilities

Section 3.1.2 of Chapter 6 notes that site-specific topography and the characteristics of the selected construction site may require that the standard overall site arrangement be tailored for a specific facility.

3.2 Interfaces

The general arrangement requirements of Section 3 of Chapter 6 of the Evolutionary Requirements Document affect the design of various plant systems discussed in other chapters of the document.

3.3 Requirements

Section 3.3 of Chapter 6 of the Evolutionary Requirements Document provides the requirements related to the arrangement of site facilities.

3.3.1 Site Drainage

Section 3.3.1 of Chapter 6 requires that the site drainage capacity be adequate to handle the local probable maximum precipitation (PMP), including runoff from adjacent topography, without flooding the site. ANSI/ANS 2.8-1981 was referenced as a guide to be used by the plant designer in establishing the PMP and site drainage requirements.

Because the staff has not reviewed ANSI/ANS 2.8-1981 for consistency with regulatory positions, in the DSER for Chapter 6, it concluded that EPRI should reference SRP Section 2.4.10, "Flood Protection Requirements," and Generic Letter (GL) 89-22, "Resolution of Generic Safety Issue No. 10: Design for Probable Maximum Precipitation," in lieu of ANSI/ANS 2.8-1981. This was identified as an open issue.

Since EPRI has revised Section 3.3.1 of Chapter 6 to reference SRP Section 2.4.10 as the basis for establishing the PMP, the staff concludes that the requirement is acceptable. Therefore, this DSER open issue is closed.

3.3.2 Site Layout

Section 3.3.2 of Chapter 6 provides the following key plant layout requirements applicable to both PWRs and BWRs:

- The location of the meteorological tower will comply with ANSI/ANS 2.5-1984, "Standard for Determining Meteorological Information at Nuclear Power Sites."

- To the extent possible, the off-gas treatment building, sewage treatment building, gaseous chlorine facilities, etc., will be located downwind of the main plant area.

- Cooling tower banks (forced draft) will be oriented so as to maximize the effect of prevailing winds. Each unit will be separated to minimize the potential for discharged air mixing with the intake air of other cooling units. Towers will be located so that their failures will not jeopardize seismic Category I structures.

- The main circulating water intake and discharge structures and the turbine building will be located so as to minimize the construction and maintenance costs of the circulating water system.

<u>Embedment</u>

Section 3.3.2.5 of Chapter 6 states that standard levels of embedment are important to the success of the standard plant and specifies the standard levels of embedment for both the BWR reactor building and the PWR containment structure and auxiliary building. In the DSER for Chapter 6, the staff pointed out that the original requirement in Section 3.3.2.5.2 was incorrect in specifying one level of embedment for the PWR containment building because this contradicted the two levels of embedment shown in Figure 6.D-8 of Appendix D to Chapter 6. This was identified as a confirmatory issue. EPRI has revised Section 3.3.2.5.2 of Chapter 6 and has deleted the one-level embedment specification for the PWR containment building. This resolves the discrepancy and is acceptable. Therefore, this DSER confirmatory issue is closed.

Also, Appendices B and C to Chapter 6 originally showed the typical embedment of about 50 feet for the BWR building and 40 feet for the PWR containment building. These levels contradicted the 25- to 30-foot standard embedment specified in Section 2.1.7.1 of Chapter 6. By letter dated April 24, 1991, the staff requested that EPRI explain this difference. In its response dated July 2, 1991, EPRI stated that the intent of the requirement in Section 2.1.7.1 is to provide a further clarification of the founding material bearing capacity requirement specified in Table 1.2-6 of Chapter 1. EPRI also stated that the standard plant embedment levels specified in Section 3.3.2.5 are based on tradeoffs among founding material bearing capacity, construction cost, and maintenance access and considerations. The staff concludes that EPRI's explanation of the difference in embedment depths is acceptable.

Plant Grade

Section 3.3.2.6 of Section 6 had required that plant grade be established at an elevation higher than the probable maximum flood (PMF) elevation as defined in ANSI/ANS 2.8-1981, including consideration of the effect of wave runup and splash for sea-side and lake-side locations. In the DSER for Chapter 6, the staff requested that the reference to ANSI/ANS 2.8 be replaced by SRP Section 2.4.10 and identified this as an open issue. EPRI has revised Section 3.3.2.6 of Chapter 6 and has specified SRP Section 2.4.10 as the basis for establishing the PMF elevation. The staff concludes that this is acceptable; therefore, this DSER open issue is closed.

Other Safety-Related Site Layout Requirements

Section 3.3.2.8 of Chapter 6 states that buildings and facilities in which hazardous materials will be handled will not be located near the control room and the plant designer will perform an analysis to identify potential hazards. Regulatory Guide 1.78, "Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," is referenced for guidance. The staff concludes that these requirements are acceptable.

3.3.3 External Interfaces

Section 3.3.3 of Chapter 6 requires that the plant designer identify water supplies, site drains, culverts, sewer connections, incoming and outgoing power connections, and transportation facilities on the site arrangements drawings. The staff recognizes that it is desirable that plant design drawings match plant as-built conditions and concludes that the requirements in this section are acceptable.

3.3.4 Service Facilities

Section 3.3.4 of Chapter 6 specifies the requirements for service facilities. Included within the scope of the Evolutionary Requirements Document are requirements related to:

- the accommodation of normal operating staff, permanent support staff, contract workers, additional personnel required during outages, regulatory personnel, and visitors
- space dedicated for future expansion
- warehouse facilities

The design of the plant service facilities will be based on both the number and type of persons entering the plant and how often they enter the plant. These facilities will be sized to accommodate the normal staff complement as well as contract workers and others needed for plant outages. Adequate change room, office, locker, and parking facilities are important to accommodate large outage work crews and to facilitate plant outage operations.

To implement these requirements, the ALWR designer, applicant, or owner is expected to identify the number of personnel in each category on the basis of operations and maintenance requirements. The requirements in Section 3.3.4 of Chapter 6 for the warehouse facilities will help minimize delays in moving equipment, recordkeeping requirements, radiation exposure and radiological controls, and vehicle entries within the protected area. The staff concludes that the requirements of Section 3.3.4 of Chapter 6 will facilitate ALWR licensees' compliance with regulatory requirements concerning recordkeeping, health physics, and physical security and are acceptable.

3.3.5 Repair Shops

Section 3.3.5 of Chapter 6 provides the requirements related to repair shops, including the following:

- clean shops - machine, welding, sheet metal, electric, instrumentation, insulation, paint, and carpentry shops and associated tool rooms
- decontamination shop
- contaminated shops - machine, electric, instrumentation, seal overhaul, control rod drive mechanism overhaul (BWR), calibration and equipment and tool decontamination shops and associated tool rooms
- contractor fabrication shops

Repair Shop Capabilities

Each shop will have the necessary space, tools, machines, storage, ventilation and temperature-humidity controls, communications, lifting equipment, drainage, and monitoring equipment. Facilities will be provided for testing contaminate and uncontaminated relief valves. The seal overhaul shop will be equipped so that the mechanical shaft seals of reactor coolant pumps, feed pumps, and other pumps can be overhauled on site.

Repair Shop Locations

Machine, piping, welding, and carpentry shops will be accessible by road. Clean shops will be located to enable passage between each shop and the installed equipment it serves without the need to pass manned security check points or radiological control points. The decontamination shop will be located adjacent to the hot machine shop.

The staff concludes that the provision of increased onsite repair capability and improved access and arrangements required by Section 3.3.5 of Chapter 6 will facilitate ALWR licensees' compliance with regulatory requirements concerning health physics and physical security and are acceptable.

3.3.6 Utility Routing

Section 3.3.6 of Chapter 6 specifies the requirements related to the design of duct banks, pipe tunnels, and pipe chases. Duct banks for Class 1E service will be independently supported and separated from adjoining structures. Equipment for different trains will be in different duct banks. Pipe tunnels and pipe chases will be provided with the personnel access holes, manways, lighting, ladders, and ventilation necessary for construction, maintenance, and inspection activities. The Evolutionary Requirements Document prohibits the embedment of conduit. The design of duct banks, pipe tunnels, and pipe chases will ensure that drainage is adequate and that drainage features do not constitute a flooding path to lower levels. The staff concludes that the requirements of Section 3.3.6 of Chapter 6 are consistent with regulatory requirements and good engineering practice and are, therefore, acceptable.

3.3.7 Miscellaneous Site Facilities

Section 3.3.7 of Chapter 6 refers to Chapter 2, "Power Generation Systems," and Chapter 9, "Site Support Systems," for the requirements for the auxiliary boiler and fire protection equipment.

3.3.8 Construction Facilities

Section 3.3.8 of Chapter 6 specifies the requirements related to facilities that will be provided for plant construction purposes. These facilities, which will include both temporary and permanent facilities, must meet the requirements specified in the construction plan required in Section 7.2.7 of Chapter 1 of the Evolutionary Requirements Document. Transportation routes will be identified and paved as appropriate. Lighting and weather protection will be adequate for triple-shift work. Adequate site drainage will be provided. A material control program and schedule will be set up early during plant construction. The staff concludes that the requirements of Section 3.3.8 of Section 6 are compatible with regulatory requirements and are, therefore, acceptable.

3.3.9 Transportation Arrangements

Section 3.3.9 of Chapter 6 states that roads and railroad tracks will be located to minimize hazards to safety-related buildings. Derailers will be provided as appropriate. The staff concludes that these requirements are compatible with regulatory requirements and are, therefore, acceptable.

3.3.10 Tanks

In the DSER for Chapter 6, the staff stated that the Evolutionary Requirements Document should specify that all outdoor liquid tanks that may contain radioactive material should have (1) a dike or retention basin capable of preventing runoff in the event of a tank overflow or failure and (2) provisions for sampling collected liquids and routing them to the liquid radioactive waste treatment systems in accordance with Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants." This was identified as an open issue.

Section 4.5.5.1 of Chapter 12 has been revised and includes a requirement for spill retention in outdoor tanks. Appendix B to Chapter 1 has also been revised and contains a commitment to meet Regulatory Guide 1.143, Revision 1. This is in accordance with the guidance in Section 11.2, "Liquid Waste Management Systems," and is acceptable. Therefore, this DSER open issue is closed.

4 POWER GENERATION COMPLEX

4.1 Introduction

Section 4 of Chapter 6 of the Evolutionary Requirements Document provides the functional requirements and identifies the special features for the power generation complex (PGC). The PGC will include the primary containment, reactor building (BWR), auxiliary building (PWR), fuel facility, turbine-generator building, radwaste facility, emergency onsite power supply facility, control building/ complex, and hot shop/outage maintenance building. Included within the boundaries of the PGC will be facilities for radiological access control, the technical support center, change rooms and lockers, food preparation and dining areas, personnel rest areas, laboratories, and special shops. Appendices B and C to Chapter 6 contain arrangement sketches and a standard site plot. For multiple-unit sites, Section 4.1.4 of Chapter 6 requires that units be duplicates of each other (i.e., mirror-image arrangements of facilities or equipment are not allowed).

4.2 Common Requirements

Section 4.2 of the Chapter 6 of the Evolutionary Requirements Document contains common requirements that are applicable to the PGC of either a PWR or a BWR.

4.2.1 Overall Arrangement

Section 4.2.1 of Chapter 6 indicates that the PGC will encompass all nuclear steam supply system and energy conversion functions. Safety-related and non-safety-related systems will be separated by structure or distance. Small-bore piping, instrument tubing, and electrical conduit will be preengineered with preestablished tolerances. Systems (e.g., piping, duct, and conduit) will be grouped and routed for installation on common supports consistent with separation requirements. Common floor and wall penetrations will be used to the extent practicable to minimize the number of penetrations and seals. Wall and floor penetrations will be oversized (providing a 3-inch clearance between the structure and the penetrating systems) and of standardized sizes to the extent practicable to simplify installation.

The staff concludes that the above general requirements established for the design of the PGC represent good design practice, are consistent with the guidelines of SRP Sections 3.4.1, "Flood Protection," 3.5.1.1, "Internally Generated Missiles (Outside Containment)," and 3.5.2, "Structures, Systems and Components To Be Protected from Externally-Generated Missiles," and are, therefore, acceptable. However, judicious care should be used in implementing Section 4.2.1.6 of Chapter 6 regarding the use of common penetrations for multiple systems. This section should not be used as a basis for reducing physical separation between different safety system divisions or in a manner that would create unacceptable common-mode failure paths or systems interactions.

4.2.2 Building and Equipment Arrangement

Section 4.2.2 of Chapter 6 specifies the general requirements related to the physical location of equipment and the routing of systems within the PGC. EPRI specifies that building structures will be used for radiation shielding to the extent practicable. Pipe penetration areas outside the containment will be separated into radioactive and nonradioactive areas. Electronic equipment will be grouped and enclosed in environmentally controlled compartments. Equipment and spaces required for postaccident operations will be arranged so that they are accessible under postaccident conditions in order to minimize personnel exposure. Radioactive and nonradioactive equipment and piping will be separated to avoid unnecessary exposure from the radioactive components when servicing the nonradioactive components. Radioactive components that are significant sources of radiation exposure will be located in separate cubicles with adequate laydown space for maintenance provided in each cubicle. Radioactive components that require little maintenance (such as filters and tanks) will be separated from radioactive components of the same system that require more maintenance (such as pumps and valves) to minimize radioactive exposure during maintenance of the more passive components. Also, redundant radioactive systems will be separated (shielded) from each other to permit maintenance on one system while the other is in service. Separate sumps will be provided for potentially contaminated drains and clean drains to prevent the spread of contamination. Cubicles containing radioactive components will have access labyrinths sized to permit the removal and replacement of the equipment within the cubicle, yet they will be designed to preclude any radiation streaming from the cubicle into the access corridor. These requirements will reduce occupational exposure and facilitate maintenance by separating radioactive and nonradioactive components and piping.

The staff concludes that the general requirements of Section 4.2.2 of Chapter 6 represent good design practice, are consistent with the guidelines of SRP Sections 3.4.1, 3.5.1.1, and 3.5.2, and are, therefore, acceptable. In addition, the above design features, which are intended to minimize occupational exposures by the separation of radioactive and nonradioactive components and piping, conform with the guidelines of Regulatory Guide 8.8 and are acceptable.

4.2.3 System Supports

Section 4.2.3 of Chapter 6 specifies the general requirements for the design of system supports. Standardized designs will be used for system supports to simplify their procurement, fabrication, erection and inspection. Supports will be defined by drawings that specify critical dimensions and tolerances. EPRI requires that a unique drawing be prepared for each support for piping meeting the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code). Typical drawings may be used for clips and small supports. System drawings will depict support locations relative to system components such as valves and elbows and will include field welding documentation. Preference will be given to the attachment of supports to structural steel or embedment plates over the use of concrete anchors. The use of hydraulic and mechanical snubbers will be minimized in favor of passive seismic devices. Similar systems will share common supports to reduce installation costs. Potential interactions between safety-related and nearby non-safety-related piping will be considered.

Section 4.2.3.2 in Chapter 6 states that supports for all non-ASME seismic Category I piping will be designed to ANSI/American Institute of Steel Construction (AISC) N-690, "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities." In a letter dated May 17, 1991, the staff stated that since it had not yet endorsed this standard for piping supports, the only acceptable rules for non-ASME seismic Category I piping are found in ANSI/ASME B31.1, "Power Piping." Therefore, the staff requested that Section 4.2.3.2 be revised to reflect this position. In a letter dated August 1, 1991, EPRI responded to this request by stating its position that a change to the Evolutionary Requirements Document was unnecessary because ANSI/AISC N-690 was developed explicitly for the nuclear industry and should be appropriate for the design of the next generation of nuclear plants. The staff does not agree with EPRI's position. The standard has not been endorsed by the staff for use in the design of supports for either structures or ASME piping. Further, it is not even under consideration by the staff for use in the design of non-ASME piping. The staff's position relative to use of this standard for ASME piping is briefly discussed in Chapter 1, Section 4.7.3 of this report. Therefore, at this time, the staff's position remains as stated above; that is, ANSI/ASME B31.1 contains the only acceptable rules for use in the design of non-ASME piping. However, when the staff endorses ANSI/AISC N-690, it will reconsider its use for ALWR plant design for each plant requesting its use. Until then, the staff will review individual applications for FDA/DC in accordance with the above position.

Section 4.2.3.5 of Chapter 6 of Revision 0 of the Evolutionary Requirements Document stated that alternative seismic restraint devices such as energy absorbers and seismic stops will be used instead of snubbers, where practicable. The only alternatives that the staff is currently accepting without a plant-specific review are those identified in ASME Code Case N-420, "Linear Energy Absorbing Supports for Subsection NF, Classes 1, 2, and 3 Construction, Section III, Division 1." The staff conditionally approved Code Case N-420 in Regulatory Guide 1.84, "Design and Fabrication Code Case Acceptability - ASME Section III Division 1," Revision 24, dated June 1986. In addition, as discussed in Section 4.7.3 of Chapter 1 of this report, one of the conditions of the staff's approval of Code Case N-411, "Alternative Damping Values for Seismic Analysis of Classes 1, 2, and 3 Piping Sections, Section III, Division 1," in Revision 24 of Regulatory Guide 1.84 is that Code Case N-411 cannot be used in analyses for piping systems in which linear energy absorbing supports covered by Code Case N-420 are used. This issue is discussed in Chapter 1, Section 4.7.3, of this report. In the DSER for Chapter 6, the staff stated that in its letter of July 3, 1989, EPRI had agreed to these staff positions and committed to revise the requirement in Section 4.2.3.5 of Chapter 6 accordingly. This was identified as a confirmatory issue.

The staff has verified that EPRI has revised Section 4.2.3.5 of Chapter 6 to require that alternative seismic restraint devices such as energy absorbers, which have been accepted in the ASME Code and by other regulatory agencies, must be used in lieu of snubbers, where practicable. The staff concludes that the revised requirement in Section 4.2.3.5 of Chapter 6, as clarified by the staff's position relative to the use of energy absorbers and its discussion in Section 4.7.3 of Chapter 1 of this report, is acceptable. Therefore, this DSER confirmatory issue is closed.

In addition, the surveillance and maintenance of snubbers have resulted in increased occupational radiation exposures resulting from problems such as fluid leakage in hydraulic snubbers and binding problems in mechanical snubbers. The placement of these snubbers in certain parts of the plant has impeded access for maintenance and operational purposes. EPRI states that the design and layout of seismic supports will take into account operation and maintenance access requirements. Use of these supports will be minimized in contaminated areas. The above proposed restrictions on the use and location of seismic supports are intended to lower the potential for occupational exposures during surveillance and maintenance operations and are, therefore, acceptable.

The staff concludes that the general requirements of Section 4.2.3 of Chapter 6, supplemented by the staff position relative to ANSI/ANS N-690, represent good engineering practice and are acceptable.

4.2.4 Piping Arrangement

Section 4.2.4 of Chapter 6 specifies the general requirements for the arrangement of piping systems. The physical arrangement of piping will include consideration of safety train separation, logical grouping of attached components, operability and maintenance and testing access constraints, water hammer, system support, crud accumulation, condensate drainage, vulnerability of electrical panels to leakage from overhead piping, the effects of flashing and cavitation, and radiation protection.

As-built records will be kept of locations of underground and embedded piping. The use of welded fittings will be minimized in favor of bending, and butt weld fitting will be used instead of socket welded fittings for ASME Class 2 and 3 piping that is more than 2 inches in diameter. Valves will be located and oriented to facilitate maintenance. Unidentified coolant leakage will be minimized by the provision of valve stem leakoff connections on packed valves larger than 2-1/2 inches in diameter in high-pressure (275 psig and above) piping containing reactor coolant. Pneumatic valves and valve controllers will be located to facilitate maintenance and to improve response time. For instrument tubing located in readily accessible areas of the plant, the Evolutionary Requirements Document allows the use of compression fittings instead of welded connections.

The following piping design features will be used to eliminate crud traps and thereby minimize the buildup of crud in radioactive piping:

- location of expansion loops in the horizontal plane
- use of butt-welded connections with long radius bends in resin piping
- connections to horizontal piping runs designed to enter the run vertically or diagonally above its center line
- minimization of low points, drains, vents, and other crud-collecting configurations
- use of butt welds without backing rings in all radioactive system piping more than 2 inches in diameter

- sloping of drain and sampling lines not continuously used during normal operations to prevent crud pockets or areas of stagnant fluids

- orientation of valve stems so that crud does not settle in the bonnets

- flow-restricting devices designed to minimize crud accumulation

These piping design features conform with the guidelines of Regulatory Guide 8.8 for crud reduction and are acceptable.

The Evolutionary Requirements Document states that each valve or pump that handles radioactive fluid and is not self-draining will have a designated drain path to a floor drain. All floor drains from potentially contaminated areas will be shielded if routed through a clean area that is normally or periodically occupied. In addition, floor drains will have adequate traps to prevent radioactive gas from moving from compartment to compartment through the drain lines. All valves will be readily accessible for maintenance. Those valves located in high-radiation areas will be operated, where practicable, by controllers located outside the high-radiation areas. These features are intended to reduce occupational exposure during valve maintenance and operation and are acceptable.

In the DSER for Chapter 6, the staff discussed the ASME classification of safety-related instrument sensing (impulse) lines and identified it as an open issue. In Table B.1-2 of Appendix B to Chapter 1 of the Evolutionary Requirements Document, EPRI has committed to comply with Regulatory Guide (RG) 1.151, "Instrument Sensing Lines." However, the requirement in Section 4.2.4.33 of Chapter 6, Revision 3, does not agree with the guidelines of RG 1.151. The requirement states that instrument sensing lines connected to ASME fluid systems will be designed in accordance with ASME Code, Section III, and supports for these lines will be designed in accordance with ANSI/AISC N-690. This requirement should state that all safety-related instrument sensing lines will be classified as applicable in accordance with the guidelines in RG 1.151. Those lines classified as ASME Class 2 or 3 will be constructed in accordance with ASME Code, Section III, Subsection NC or ND, respectively. The only acceptable exception to these rules is supports for these lines. Supports must be designed, but not necessarily constructed, to the rules in ASME Code, Section III, Subsection NF. Supports should be seismic Category I and the pertinent quality assurance requirements of Appendix B to 10 CFR Part 50 should be applied to all activities affecting the safety-related functions of these supports. As stated in Section 4.2.3 of this chapter, the staff has not yet endorsed ANSI/AISC N-690 for the design of piping supports but will reconsider its use for each application contingent on its endorsement of a particular version. Until then, the staff will review individual applications for FDA/DC in accordance with the above position. Therefore, this DSER open issue is closed.

The staff concludes that the requirements of Section 4.2.4 of Section 6, supplemented by the above staff position, constitute good piping design practice that are consistent with the staff's review criteria and are, therefore, acceptable.

4.2.5 Heating, Ventilation, and Air Conditioning (HVAC)

Section 4.2.5 of Chapter 6 specifies the general requirements for the HVAC systems for the PGC. All HVAC filtration, cleanup, and pressurization equipment required for the control room will be located within the control complex pressure boundary to minimize inleakage and outleakage. Shake spaces between building walls and/or slabs of potentially contaminated cubicles will be sealed to control boundary integrity. HVAC intake and exhaust discharge structures will be located so as to minimize reentrainment. Equipment and ducts will be located so that they will not be exposed to the weather. To prevent the spread of contamination, the HVAC system will route air from cleaner areas to contaminated or potentially contaminated areas. HVAC duct penetrations through rooms and cubicles containing potentially high-radiation sources will be located above head level so that personnel outside the rooms or cubicles will not be exposed to radiation streaming from inside the rooms or cubicles. These HVAC design features are consistent with the guidelines of Regulatory Guide 8.8 and are, therefore, acceptable.

However, the ALWR designer or applicant will be required to provide a description of airborne radioactive material sources in the plant to be considered in the design of personnel protective measures and for dose assessment. This description should include a tabulation of the calculated concentrations of radioactive material, by nuclide, expected during normal operation, anticipated operational occurrences, and accident conditions for equipment cubicles, corridors, and operating areas normally occupied by operating personnel, and should include models and parameters for the calculations.

The remainder of the staff's evaluation of the HVAC systems is given in Chapter 9 of this report.

4.2.6 Electrical Arrangement

Section 4.2.6 of Chapter 6 specifies the general electrical arrangement requirements for the PGC. Electrical cable will be located sufficiently distant from high-temperature piping, in accordance with NUREG-0588, "Interim Staff Position on Environmental Qualification of Safety Related Electrical Equipment," November 1979, to avoid ampacity derating or the use of thermal barriers. Multilevel cable trays will be sufficiently separated to facilitate the use of cable pulling equipment. Conduit entering electrical devices from the top, and where necessary for device qualification, will be provided with drip loops. Lightweight conduit, fittings, and cable tray materials will be used where technically acceptable. Cable tray supports will be mounted on floors rather than hung from ceilings, where technically acceptable, to facilitate modularization and cable pulling. Precast trenches, duct banks and manholes will be used, where technically acceptable, to accelerate construction. Cable pulling plans will be developed during the design of equipment, cable tray, and conduit layouts and will be made available to the constructor. Multipaired conductors will be color coded to minimize labeling costs. For the installation of the ground grid cable, wedge-pressure connectors will be used instead of exothermic cadweld connections in accessible, dry locations. As previously stated, Electrical cable will be located sufficiently distant from high-temperature piping, in accordance with NUREG-0588, to avoid ampacity derating or the use of thermal barriers. In the DSER for Chapter 6, the staff stated that EPRI, in a letter dated July 3, 1989, had committed to clarify Section 4.2.6.2 of Chapter 6, concerning the requirements for vertical separation between trays in a multilevel cable tray system, to specify that the vertical separation was only within a single safety division of a multilevel cable tray system or within non-safety-related multilevel cable tray systems. This was identified as a confirmatory issue in the DSER. The staff has verified that EPRI has revised Section 4.2.6.2 of Chapter 6 to address the requirements for vertical separation and horizontal spaces between adjacent trays of the multilevel cable tray systems within a safety division and the requirements for separation between cable trays for redundant safety divisions or between safety and non-safety-related divisions. The staff concludes that these changes meet its guidelines and are acceptable. Therefore, this DSER confirmatory issue is closed.

In the DSER for Chapter 6, the staff stated that in its July 3, 1989, submittal, EPRI had committed to revise Section 4.2.6.4 of Chapter 6 concerning the use of lightweight conduit, fittings, and cable tray materials to specify that the plant designer will be required to ensure that conduit and cable tray materials used as barriers meet the requirements of Institute of Electrical and Electronics Engineers (IEEE) 384, "IEEE Trial-Use Standard Criteria for Separation of Class 1E Equipment and Circuits," 1974. This was identified as a confirmatory issue in the DSER. The staff has verified that EPRI has revised Section 4.2.6.4 of Chapter 6 to specify that the conduits and cable tray materials used as barriers meet the requirements of IEEE 384. The staff concludes that the changes meet its guidelines and are acceptable. Therefore, this DSER confirmatory issue is closed.

In the DSER for Chapter 6, the staff stated that EPRI, in a letter dated July 3, 1989, had committed to revise Section 4.2.6.10 of Chapter 6 to specify that aisles and corridors will be assigned to one of the safety trains. This was identified as a confirmatory issue in the DSER. The staff has verified that Section 4.2.6.10 of Chapter 6 has been revised to require that, for purposes of cable tray routing, aisles and corridors will be designated (assigned) to individual safety divisions, as appropriate to minimize potential conflicts with separation requirements. The staff concludes that this requirement is acceptable. Therefore, this DSER confirmatory issue is closed.

The staff concludes that the requirements of Section 4.2.6 of Chapter 6 of the Evolutionary Requirements Document represent good electrical arrangement practice and are acceptable.

4.2.7 Inservice Inspection Considerations

Section 4.2.7 of Chapter 6 specifies the general access requirements for inservice inspections (ISIs) performed in radiation areas to ensure minimum occupational radiation exposure. Piping and pipe support locations, insulation, hangers, and stops will be designed so as not to interfere with inspection equipment and personnel. Piping welds will be adequately separated to perform ISI, and platforms or walkways will be provided to access these welds. Radial clearances of 6 inches will be provided around pipe and component welds requiring volumetric or surface examination. Supports will be located so as not to interfere with ISI or will be portable. This section requires that tees, valves, fittings, attachments, and pumps not be joined together but be separated by sections of piping. Welds in piping penetrating walls will not be located so that the wall interferes with weld ISI. Section 4.2.7.5 of Chapter 6 specifies that reliable position indicators will be provided on safety-related check valves. Permanent access platforms will also be provided outside reactor pressure vessel shield walls to facilitate ISI of the reactor vessel and nozzles. To reduce occupational exposure, mechanized inspections will be considered for areas where radiation levels exceed 50 mrem/hour or where physical limitations restrict or prevent manual methods.

The staff concludes that the access requirements of Section 4.2.7 of Chapter 6 for inservice inspection are in accordance with the recommendations of the Atomic Industrial Forum, Inc. (AIF) study reported in AIF/NESP-020, "Compendium of Design Features To Reduce Occupational Radiation Exposure at Nuclear Power Plants"; comply with the guidelines of Regulatory Guide 8.8; represent desirable design practice; and are acceptable with respect to as low as is reasonably achievable (ALARA) considerations.

However, Section 4.2.7.1 of Chapter 6 states that the functional requirements for inservice inspection will be as defined in Section XI of the ASME Code, supplemented by NRC guidelines as specified in the SRP. In SECY-90-016, "Evolutionary LWR Certification Issues and Their Relationship to Current Regulatory Requirements," and in the DSER for Chapter 5 of the Evolutionary Requirements Document, the staff concluded that the requirements of Section XI of the ASME Code provide certain information on the operational readiness of the components, but in general, do not provide the information needed to verify the capability of the components to perform their intended safety functions. It is the staff's judgment that the code does not ensure the necessary level of component operability that is desired for the evolutionary LWR designs. In SECY-90-016 and in its April 27, 1990, response to comments by the Advisory Committee on Reactor Safeguards, the staff recommended enhanced criteria for inservice testing of pumps and valves that will facilitate inservice inspection of the components. In its staff requirements memorandum of June 26, 1990, the Commission endorsed the staff's position. In the DSER for Chapter 6, the staff concluded that the requirements in Section 4.2.7 of Chapter 6 of the Evolutionary Requirements Document were not consistent with its position on this matter and identified this as an open issue.

In a letter dated May 22, 1991, EPRI responded to this DSER open issue by stating that the ALWR requirements for inservice testing of pumps and valves are found in Chapter 1, Sections 12.1, 12.3, and 12.4. EPRI further stated that Chapter 6 only requires that the needs of inservice inspection activities be considered in building design and arrangement. The staff agrees with EPRI's response and its evaluation of EPRI's inservice testing requirements for pumps and valves is found in Chapter 1, Section 12.2, of this report. Therefore, this DSER open issue is closed.

4.2.8 Radiation Zones and Shielding

Section 4.2.8 of Chapter 6 specifies the general design requirements related to radiation zones and shielding.

EPRI specifies that radioactive equipment will be located in shielded compartments and that shielding will be provided between radioactive and nonradioactive components and between redundant radioactive components located in the same cubicle. Removable local shielding will be provided for equipment that could exceed the radiation zone designation. Space, support points, and handling facilities will be provided for the placement of this temporary shielding. Local control panels will be located in low-radiation areas. Buildings will be arranged so as to make maximum use of common walls and floors for shielding. Radioactive piping running through normally accessible areas will be routed through shielded pipe chases to minimize occupational exposure to personnel.

The staff concludes that the above requirements of Section 4.2.8 represent good design practice and are acceptable. Because the staff is concerned about the excessive number of potential radiation overexposure events involving reactor cavities and fuel transfer tubes that have occurred in operating reactors in spite of NRC information notices and civil penalties, it will, in its reviews of individual applications for FDA/DC, pay particular attention to access controls and shielding provisions provided for these areas.

The radiation zones established, along with the radiation source terms, will provide the basis for the access control measures, building layout, equipment design and layout to maintain assigned radiation levels, and radiation shielding and calculation of shielding thickness.

The staff concludes that the above shielding design features conform with the guidelines of Regulatory Guide 8.8 and are acceptable.

4.2.9 Design of High-Radiation Areas

Section 4.2.9 of Chapter 6 specifies the general requirements related to the design of high-radiation areas. EPRI specifies that ALWRs will be designed to minimize or eliminate the need for personnel to enter areas where the dose rate will be greater than 100 mrem/hour during routine operation.

The following design features are intended to minimize radiation levels where personnel are required to perform operational and maintenance functions:

- Remote viewing devices will be provided for routine visual surveillance.

- Valve operators, instrumentation indicators, instrument isolation valves, and sensing element transmitter readouts will be located in low-radiation zones.

- Instrumentation will be designed for long service life and low frequency of maintenance and calibration.

- Reach rod shafts for valves will not block or cross corridors that must be accessed for maintenance of equipment.

- Remotely controlled TV cameras with scanning and zoom capabilities will be used for remote surveillance of high-radiation areas.

- Valves will be located and shielded to enable valve maintenance without significant exposure from nearby radioactive components.

A number of overexposures or potential overexposure events have occurred at operating reactors as a result of transient high-radiation areas (i.e., adjacent to fuel transfer tubes, in the cavity beneath the reactor vessel). The staff will review individual applications for FDA/DC to ensure that plant designers evaluate all areas where transient high radiation could be experienced and design these areas to minimize the potential for large radiation doses (greater than 100 mrem/hour) from such transient sources. This issue is addressed further in Chapter 7 of this report. During its review of an individual application for FDA/DC, the staff will ensure that the applicant has identified all potential high-radiation areas. The staff will also review the applicant's measures to minimize inadvertent personnel exposure from these areas.

The staff concludes that the design features of Section 4.2.9 of Chapter 6 are based on those described in Regulatory Guide 8.8, will facilitate compliance with ALARA requirements, and are, therefore, acceptable.

4.2.10 Contamination Control

Section 4.2.10 of Chapter 6 specifies the general requirements for floor surface sloping, surface coatings, and tank curbs to reduce the spread of contamination and to facilitate cleanup.

Cubicles will be designed to reduce the potential for the spread of radioactive contamination and to facilitate cleanup. Floor surfaces will be sloped to drains that will be sized for cleanup water flow rates. Tanks containing contaminated liquids will be provided with curbs to contain any potential leaks or spills. Floors and walls of cubicles that may become contaminated from radioactive leaks or spills will be protected with a smooth-surface epoxy coating to facilitate decontamination. EPRI states that ANSI N101.2-1972, "Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities," and American Society for Testing and Materials (ASTM) D3842.80 provide qualification requirements for coatings.

SRP Section 6.1.2, "Protective Coating Systems (Paints) - Organic Materials," states that applicants should also meet the quality assurance requirements in ANSI N101.4-1972, "Quality Assurance for Protective Coatings Applied to Nuclear Facilities." In the DSER for Chapter 6, the staff stated that in its letter of July 3, 1989, EPRI had committed to revise the Evolutionary Requirements Document to include this additional requirement and identified this as a confirmatory issue.

The staff has verified that EPRI has revised Section 4.3.2.7 of Chapter 6 to require that paints and coatings that will be exposed to the containment atmosphere be qualified in accordance with ANSI N101.4-1972 (including the quality assurance requirements) and ASTM D3842.80. The staff concludes that these revisions are acceptable; therefore, the DSER confirmatory issue is closed.

In addition, during its reviews of individual applications for FDA/DC, the staff will evaluate coatings in accordance with SRP Section 6.1.2.

The staff concludes that the requirements of Section 4.2.10 of Chapter 6 of the Evolutionary Requirements Document represent good design practice for minimizing the spread and facilitating the cleanup of radioactive contamination, conform with the guidelines of Regulatory Guide 8.8 for radiation protection, and are, therefore, acceptable.

4.2.11 Structural Design

Section 4.2.11 of Chapter 6 specifies the following structural design requirements for ALWRs.

Mats and Foundations

Section 4.2.11.1 of Chapter 6 states that foundation mats [illegible] ated buildings will be separated from those of other structure [illegible] rect interaction between foundations can take place. Adjacent [illegible] d buildings with a common safety classification and same fo [illegible] ation may share a common foundation. Foundations and support st [illegible] will be designed to preclude leakage of potentially radioactive flu [illegible] nto the local ground water.

Interaction Between Structures

Section 4.2.11.2 of Chapter 6 states that building designs will include common floor elevations to facilitate access. Integrated structures will be used where practicable to eliminate shake spaces and to facilitate penetration design.

Building Framing

Section 4.2.11.3 of Chapter 6 states that structural steel columns will be used instead of freestanding concrete columns, where feasible, to allow for the early erection and closure of buildings and for modularization using the columns for support.

Concrete floors on structural steel beams and metal decking will be used to eliminate the need for temporary shoring.

Building Layout

Section 4.2.11.4 of Chapter 6 states that buildings external to the containment will be laid out using rectangular designs and coordinates with standardized floor level, column line, cubicle, and aisleway dimensions to facilitate the forming of the concrete.

Concrete Design

Section 4.2.11.5 of Chapter 6 states that composite drawings will be prepared for floor slabs and concrete walls and will identify all penetrations, embedments, and types of seals. Expanded metal mesh will be used in vertical joints. Consideration will be given to the use of water-reducing admixtures, particularly in areas of high rebar and embedment congestion.

EPRI requires that large, freestanding walls be designed for slipforming concrete placement. Concrete walls will be placed to line up between floor levels where possible.

Embedment plates will be standardized, compatible with the reinforcing steel pattern, and will be designed and sized to accommodate their own plate tolerances in addition to attachment tolerances.

In a letter dated April 24, 1991, the staff requested that EPRI address the following items: (1) construction joints and water stops, (2) construction sequence and associated loading, (3) asymmetrical loadings on the mat, (4) potential for differential settlement between lightly loaded and heavily loaded portions of the mat, (5) effect of varying concrete thickness with

Mats and Foundations

Section 4.2.11.1 of Chapter 6 states that foundation mats for safety-related buildings will be separated from those of other structures so that no direct interaction between foundations can take place. Adjacent safety-related buildings with a common safety classification and same foundation elevation may share a common foundation. Foundations and support structures will be designed to preclude leakage of potentially radioactive fluids into the local ground water.

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In its letter dated July 2, 1991, EPRI acknowledged the importance of these considerations in the design process. However, EPRI believes that these considerations are similar to those necessary for proper design of independently founded structures. EPRI noted that construction joints and construction equipment loadings are addressed by American Concrete Institute (ACI) 349 and these considerations can be just as significant for individual buildings as for integrated structures on a common basemat. Regarding the potential for differential settlement, EPRI stated that the use of a common basemat actually enhances the performance of structures because the basemat and principal walls and slabs above the basemat provide continuity across designated building boundaries; hence, the basemat will be stiffened by the buildings that tend to act as one integrated unit. Shear load transfer from heavily loaded portions of the building complex to more lightly loaded areas would be more difficult, but the interconnecting shear wall matrix will facilitate this load transfer. The staff concludes that EPRI's response is acceptable and will evaluate the adequacy of a detailed structural design during its review of an individual application for FDA/DC.

Reinforcing Steel Design

Section 4.2.11.6 of Chapter 6 states that where lap splices are not practical for reinforcing steel splices, thread-deformed, taper-threaded, and swaged reinforcing steel splices may be used instead of ferrous filler metal splices. Reinforcing steel patterns will, where possible, be rectilinear rather than radial or circumferential.

EPRI has revised Section 4.2.11.6.4 of Chapter 6 to require the plant designer to evaluate the potential for corrosion of reinforcing bars at intake structures exposed to salt or brackish water and to provide for epoxy-coated rebars in such highly corrosive environments. The staff concludes that the use of epoxy-coated rebars for preventing corrosion is acceptable. However, EPRI should consider including a criterion (or requirement) for calculating the development length, because the epoxy coating will reduce the bonding between the rebar and concrete. The staff will evaluate this issue during its review of an individual application for FDA/DC.

Structural Steel Design

Section 4.2.11.7 of Chapter 6 states that uniform depths, lengths, and connections will be used for structural steel beams and columns. Bolted connections instead of welded field connections will be used for structural steel framing where feasible. Load indicator bolts will be used where possible.

Platforms, Ladders, and Stairways

Section 4.2.11.8 of Chapter 6 states that stairways in concrete buildings will be designed in a freestanding, structural steel frame for modular installation.

During plant outages, the setup and breakdown of temporary scaffolding in radiological control areas can be a significant contributor to outage dose. EPRI specifies that permanent platforms will be provided in areas of multiple construction and inspection operations instead of multiple temporary scaffolding setups. This will result in lower occupational exposure as well as less congestion in radiological control areas during outages. To facilitate access, especially in high-radiation areas, stairways are preferable to ladders. This staff concludes that these features are intended to lower occupational exposure and are, therefore, acceptable.

Conclusion

The staff concludes that the requirements of Section 4.2.11 of Chapter 6 are consistent with applicable codes and standards, do not conflict with current regulatory requirements, and are, therefore, acceptable.

4.2.12 Construction Requirements

Section 4.2.12 of Chapter 6 contains the following construction requirements.

Modularization of Structures and Components

Section 4.2.12.1 of Chapter 6 states that the plant will be designed to accommodate modularization of structures and components in accordance with Chapter 1 of the Evolutionary Requirements Document. Where feasible, module design will incorporate the building structural framing as a support for the internal components of the module. Templates, support framing, and lifting devices will be designed and fabricated with the modules. Modules will be transportable by rail or truck. Preassembly areas and shops on the site will be designed to accommodate the modules. Helicopters will be used where practicable for placing modules. Modularization is intended to provide improved quality control and safety during construction.

Construction Access

Section 4.2.12.2 of Chapter 6 states that the permanent plant monorails, hoists, and elevators will be installed as early as possible for improved access during construction. The designer will develop an inspection program to ensure that monorails and hoists are in good condition. Drawings will depict locations of lifting and hoisting devices. Building foundations and structures will be designed to support tower cranes as determined to be necessary by the construction plan.

Construction Tolerances

Section 4.2.12.3 of Chapter 6 states that construction and fabrication tolerances for each engineering discipline will be consistent with industrial practice and identified on the respective drawings. Tolerances will not be specified to dimensions more precise than necessary. Personnel in each discipline will be made aware of the tolerances used by personnel in the other disciplines.

Conclusion

The staff concludes that the requirements of Section 4.2.12 of Chapter 6 are consistent with regulatory requirements and guidance and are, therefore, acceptable.

4.2.13 Crane Path Routing

Section 4.2.13 of Chapter 6 requires that safe load paths be developed for moving all heavy or critical loads above and across the areas served by all cranes in the power generation complex.

The staff concludes that this requirement is consistent with the requirements of NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants," and is, therefore, acceptable.

4.3 Primary Containment Structure

4.3.1 Definition

Chapter 5 of the Evolutionary Requirements Document contains the principal design criteria for BWR and PWR primary containment structures and the functional requirements for the containment system's performance and features. Chapter 1 defines the structural requirements. Section 4.3 and applicable portions of Sections 2 and 4.2 of Chapter 6 define the requirements for the design of ALWR primary containment structures. The staff's evaluation of the containment and the associated systems is provided in Chapters 1 and 5, respectively, of this report.

Additional Commission policy discussions applicable to the design features that EPRI proposes for the primary containment structure are provided in the Commission's staff requirements memorandum (SRM) of June 26, 1990, on SECY-90-016. Sections 4.3.2 through 4.3.4 of this chapter contain a summary of the design requirements of Section 4.3 of Chapter 6 of the Evolutionary Requirements Document as well as the staff's evaluation of certain proposed criteria not discussed in Chapters 1 through 5 of this report.

4.3.2 Common Requirements

Section 4.3.2 of Chapter 6 delineates the common requirements for primary containment structures.

Storage for Reactor Internals

Section 4.3.2.2 of Chapter 6 states that space within the primary containment will be adequate for the underwater storage, inspection, and repair of reactor internals during refueling.

Maintenance Work Spaces

Section 4.3.2.3 of Chapter 6 states that the primary containment will include formally designated maintenance work spaces located in low-radiation areas at various levels. Storage areas, utilities, and communications will also be provided. A clean staging and checkout area will be provided for applying and removing protective sheeting, tape, sleeving, etc., that are used for tools and equipment.

Structural Design Requirements

Section 4.3.2.4 of Chapter 6 states that ALWR designs will take advantage of anticipated code changes that are expected to result in the elimination of diagonal rebar requirements. For example, EPRI anticipates that current code requirements for diagonal rebars in reinforced-concrete containments are likely to be eliminated in the near future. Although this requirement deviates from the SRP guidelines, the staff will review individual applications for FDA/DC against the criteria in the SRP.

Containment Mixing

For containments that are not inerted, Section 4.3.2.5 of Chapter 6 proposes a passive concept that relies on the structural configuration of the containment to promote or enhance mixing of the hydrogen within the containment. As stated in the Evolutionary Requirements Document, the use of small, enclosed spaces that contain a source of hydrogen will be avoided. As a goal, the design will minimize the use of small, unvented compartments that are long and narrow because these geometries tend to cause flame acceleration and deflagration-to-detonation transition. Gratings, instead of solid floors, will be used where permitted by separation requirements. The use of floor gratings and vents will be maximized to help encourage containment mixing.

Since the Evolutionary Requirements Document only provides general goals, the staff can only observe that the design goals provided for such a passive mixing system, with no forced mixing, would tend to promote mixing. This was identified as an open issue in the DSER for Chapter 6. The staff will review individual applications for FDA/DC for those specific features that encourage mixing and could reasonably ensure that local concentrations of hydrogen in small compartments do not exceed detonation limits. Global combustible gas limits within the containment must still meet the criteria in 10 CFR 50.34(f). Therefore, this DSER open issue is closed.

Reactor Vessel Cavity/Drywell

Section 4.3.2.6 of Chapter 6 states that provisions will be available for flooding PWR reactor cavities and BWR drywells with water to cool core debris in the event of a severe accident involving reactor vessel melt-through. This section requires that the cavity/drywell arrangement preclude direct contact between core debris and the containment boundary. According to EPRI, a minimum 3-foot-thick concrete barrier will protect the leak tight boundary with water covering the core debris.

As noted in Section 4.3.1 of this chapter, the staff's evaluation of the design of the reactor vessel cavity/drywell is provided in Chapter 5 of this report. In addition, in its SRM on SECY-90-016, the Commission approved the staff's position that evolutionary ALWR designs should provide sufficient cavity floor space to enhance the spreading of core debris and provide for quenching of the debris in the reactor cavity.

The Evolutionary Requirements Document and the evolutionary ALWR designs provide a number of design features that are intended to mitigate the effects of a molten core. Among these features are a floor sizing criterion of 0.02 m^2/megawatt thermal (MWt) and provisions to flood the lower drywell or reactor cavity. This criterion was identified as an open issue in the DSER for Chapter 6.

The staff does not support or dispute the EPRI floor sizing criterion of 0.02 m^2/MWt. Instead, it concludes that it is appropriate to review the specific vendor designs to determine how they have addressed the quenching of debris in the reactor cavity and whether there is a sufficient level of protection for the containment shell/liner in addition to the floor sizing criterion. The staff will determine if the provisions provided by EPRI have increased the level of protection relative to core debris coolability. But it does not intend to consider the "core-on-the-floor" accident as a new design-basis accident. However, the staff does expect that the plant designer will have considered all mitigative features to the extent practicable to minimize the above effects associated with a core-on-the-floor accident. In particular, the designer should consider the effects of an unquenched core debris bed to assess the limits of the design.

The staff concludes that EPRI has provided sufficient guidance for the plant designer and will review individual applications for FDA/DC as indicated above. Therefore, this DSER open issue is closed.

Coating Qualification Requirements

Section 4.3.2.7 of Chapter 6 of the Evolutionary Requirements Document had stated that paints and coatings that will be exposed to the containment atmosphere will be qualified in accordance with ANSI N101.2-1972 and ASTM D3842-80 to prevent the degradation of emergency core cooling system pump performance as a result of blockage of sump strainers and screens by unqualified coatings that may come off surfaces during a loss-of-coolant accident (LOCA).

SRP Section 6.1.2 states that paints and coatings should also meet the quality assurance requirements in ANSI N101.4-1972. In its letter of July 3, 1989, EPRI committed to revise the Evolutionary Requirements Document to include this ANSI standard. This was identified as a confirmatory issue in the DSER.

The staff has verified that EPRI has revised Section 4.3.2.7 of Chapter 6 to require that paints and coatings that will be exposed to the containment atmosphere be qualified in accordance with ANSI N101.4-1972 (including the quality assurance requirements) and ASTM D3842-80. The staff concludes that these revisions are acceptable; therefore, the DSER confirmatory issue is closed.

In addition, during its reviews of individual applications for FDA/DC, the staff will evaluate coatings in accordance with SRP Section 6.1.2.

The staff concludes that the requirements of Section 4.2.10 of Chapter 6 of the Evolutionary Requirements Document represent good design practice for minimizing the spread and facilitating the cleanup of radioactive contamination, conform with the guidelines of Regulatory Guide 8.8 for radiation protection, and are, therefore, acceptable.

Subcompartment Design

Section 4.3.2.8 of Chapter 6 states that any cubicles containing high-energy lines will be vented to limit pressure and temperature buildup to below the design values for the cubicle boundaries and safety-related equipment.

This requirement establishes compliance with SRP Section 6.2.1.2, "Subcompartment Analysis," and is acceptable. Leak-before-break qualification may be used, in accordance with Section 3.6.3, "Leak-Before-Break Evolution Procedures," of the SRP (August 1987 draft), in establishing the design parameters. The staff's detailed evaluation of the leak-before-break methodology is provided in Section 4.5 of Chapter 1 of this report.

The staff concludes that the requirements of Section 4.3.2 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to determine if the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document must demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.3.3 BWR Primary Containment Structure

Section 4.3.3 of Chapter 6 specifies that the BWR containment will be reinforced concrete, steel lined, and integral with the reactor building as described in Section 7 of Chapter 5. The designer will clearly identify the primary containment pressure boundary within the reactor building. EPRI states that the integral primary containment and reactor building has no precedent in the United States and that no concrete primary containment structure has met the requirements for Code Symbol Stamps. The primary containment will consist of a drywell and suppression chamber (wetwell) connected by a vent system. Wetwell-to-drywell vacuum breakers will be provided as described in Section 7.2 of Chapter 5. Section 4.3.3.5 of Chapter 6 states that the plant designer should attempt to eliminate the need for reactor building-to-containment vacuum breakers to improve the simplicity of design and operation.

Drywell and Associated Structures

Section 4.3.3.6 of Chapter 6 states that the pedestal for the reactor pressure vessel and reactor shield wall will be fabricated steel structures filled with concrete. Section 4.3.3.7 of Chapter 6 states that the upper drywell will be provided with both a personnel air lock and an equipment hatch. The hatch will be located at or near the elevation of the safety-relief valve (SRV) and main steam isolation valve (MSIV) air operators to reduce time spent by personnel in the drywell. Access to the lower drywell will be via an equipment tunnel and a personnel air lock on the same level as the equipment platform. The staff will review individual applications for FDA/DC to ensure that the requirements of 10 CFR 73.55(d)(8) regarding access to the reactor containment, including access during shutdown, are met to reduce the threat of sabotage to these facilities.

To facilitate maintenance of reactor internal pumps, control rod drives, and incore instrumentation, Section 4.3.3.7 of Chapter 6 specifies that an equipment platform and hoisting facilities will be provided under the reactor pressure vessel in the lower drywell. Specific tools and other equipment regularly used to perform this maintenance will also be located in the drywell to improve the effectiveness of working in the drywell. EPRI states that these tools will be of the highest reliability and will require minimal maintenance. The above features are intended to minimize unnecessary traffic in the drywell during outages and thereby reduce personnel exposures.

In its letter dated July 3, 1989, EPRI stated that the shielding and arrangements of the advanced BWR design will be such that movement of irradiated fuel from the reactor vessel to the fuel pool will not restrict access to the drywell for maintenance or inspection activities. Transfer of irradiated fuel from the reactor vessel into fuel storage can result in potentially lethal radiation levels in upper levels of the drywell if, during such transfer, the spent fuel assembly were to be dropped during movement over the reactor vessel/fuel pool boundary area. Other fuel rod configurations during fuel transfer could also result in very high radiation levels in portions of the drywell. Because the Evolutionary Requirements Document did not describe those design features of the advanced BWR that will preclude the occurrence of potentially lethal radiation levels in portions of the drywell during the transfer of irradiated fuel from the reactor vessel into fuel storage, the staff identified this as an open issue in the DSER for Chapter 6. The staff concludes that it will review applications for FDA/DC to ensure that potential high-radiation areas are identified and design measures are provided to preclude potentially high radiation exposure to personnel. Therefore, this DSER open issue is closed.

Suppression Chamber (Wetwell)

Section 4.3.3.8 of Chapter 6 states that the wetted surfaces of the wetwell and vent system will be made of clad or solid Type 304L stainless steel. Cladding will have a minimum thickness of 1/8 inch. Personnel access will be via a hatch. The hatch will be 4 feet in diameter or larger, if necessary, for handling large maintenance items. A platform, accessible via a staircase, will be provided above the pool surface for inspection and maintenance. Ladders will be provided to the bottom of the pool. Section 4.3.3.9 of Chapter 6 specifies that quenchers and emergency core cooling system (ECCS) suction strainers will be located to minimize air ingestion during SRV operation with the ECCS in service. Section 4.3.3.10 of Chapter 6 states that the spray header will be located at the top of the wetwell.

Vent System

Section 4.3.3.11 of Chapter 6 states that the vent system and suppression pool will be designed to ensure adequate thermal mixing under both LOCA and long-term blowdown conditions.

SRV Piping

Section 4.3.3.12 of Chapter 6 states that the length and number of bends in SRV piping will be minimized. Horizontal runs in submerged piping will be avoided. The design of the SRV connections to the piping will provide for the use of nut setters and stud tensioners and will permit any SRV to be removed without disturbing an adjacent SRV.

Conclusion

The staff concludes that the requirements of Section 4.3.3 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document must demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.3.4 PWR Primary Containment Structure

Section 4.3.4 of Chapter 6 specifies that the primary containment structure for a PWR will be a large, dry-type containment with a cylindrical steel pressure vessel. A reinforced-concrete secondary shield building will enclose the primary containment vessel. The vessel will be approximately 150 feet in diameter. The reactor pressure vessel and reactor coolant loop will be offset within the containment. EPRI states that the large diameter and offset were chosen to provide increased operating deck working space and improved outage laydown arrangements.

One of the more dose-intensive jobs at PWRs involves the replacement of steam generators. Section 4.3.4.3 of Chapter 6 states that the containment arrangement will permit the removal and replacement of all steam generators during a 120-day plant shutdown. The maintenance hatch will be sized for the removal and replacement of a reactor coolant pump and will be located in the same containment building quadrant and on the same level as the health physics access control area. This will facilitate access to and egress from the containment during outages (thereby minimizing unproductive time and effort) and will improve control of the spread of radioactive contamination.

In-Containment Refueling Water Storage Tank

Section 5.4.3.11 of Chapter 5 requires that the containment include an in-containment refueling water storage tank (IRWST); Section 4.3.4.4 of Chapter 6 contains additional provisions for the IRWST. The containment will be arranged with a holdup volume of 25,000 gallons at the lowest floor to prevent water draining to the floor from returning directly to the IRWST.

Features To Minimize Offsite Doses

As discussed by the staff in the DSER for Chapter 5, EPRI stated that the containment spray will be used as both a containment heat removal system and a fission product cleanup system. Section 4.3.4.5 of Chapter 6 of the Evolutionary Requirements Document states that the spray headers and nozzles will be arranged to provide at least 90 percent coverage by volume. Unsprayed areas will be provided with vents and gratings to promote mixing. EPRI indicates that analyses will be based on an assumed containment design leakage rate of 0.5 percent per day. The reactor pressure vessel cavity will be designed to minimize the potential for direct containment heating in the event of a severe accident with high-pressure reactor pressure vessel failure. This feature involves the inclusion of a preferential flow path for core debris and a core debris collection volume.

As discussed by the staff the DSER for Chapter 5, the proposed containment leak rate of 0.5 percent per day represented a significant relaxation of the containment leak rate. The staff was concerned that the basis for this relaxation stemmed from the application of new approaches to the source term. This was identified as an open issue in the DSER for Chapter 6. However, in its evaluation of this issue in Chapter 5 of this report, the staff has concluded that the 0.5-percent allowable containment leakage is acceptable, provided the calculated doses for a design-basis accident meet the requirements of 10 CFR Part 100, based on analyses using the revised source term. Therefore, this open issue is closed.

Features To Minimize Local Accumulation of Hydrogen

Section 4.3.4.6 of Chapter 6 states that the PWR containment building arrangement will ensure that all compartments that could receive discharge from the primary system in a severe accident before vessel failure will discharge directly into the main natural circulation flow loop within the containment for adequate mixing capability.

Access Penetrations

Section 4.3.4.7 of Chapter 6 states that three access penetrations into containment will be provided: (1) a maintenance hatch located at grade and sized for movement of large equipment and the removal of a reactor coolant pump motor, seal ring, or multistud tensioner; (2) a personnel air lock located at the operating deck level; and (3) a second personnel air lock located at the same level as the maintenance hatch below the operating deck. If the maintenance hatch is not large enough for the removal of an intact steam generator, the Evolutionary Requirements Document specifies that an alternative path for its removal will be provided, such as an equipment hatch on the operating deck level, or for removing the containment shell. Movement of equipment through a hatch will not require passage over the refueling canal. Penetrations seals will be capable of being leak tested remotely from low-radiation areas and will be capable of being changed out during an 8-hour shift. Hatch covers will be installed inside the containment so that containment pressure will increase the sealing force and will be provided with vertical guide rails and hoists. The maintenance hatch will have a permanent vestibule outside the containment that will be large enough to accommodate truck trailers 60 feet in length. Air locks will be provided with staging areas. The staff will review individual applications for FDA/DC to ensure that the requirements of 10 CFR 73.55(d)(8) regarding access to the reactor containment, including access during shutdown, are met to reduce the threat of satotage to these facilities.

Polar Crane

Section 4.3.4.8 of Chapter 6 states that a polar crane that meets all the requirements of ANSI/ASME NOG-1-1983, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)," for Type II cranes will be provided. In addition to lifting equipment or components during refueling operations, the crane will be capable of lifting a steam generator clear of its shield wall without having to remove sections of the shield wall. The electrical components of the crane, including controllers, motors, sensors, and controls, will be qualified for the design operating temperature, radiation, humidity, and mist in the containment dome and will be designed in modular plug-in form to facilitate the replacement of faulty components.

Small Cranes

Section 4.3.4.9 of Chapter 6 states that a minimum of two small (10-ton) jib cranes will be provided on the operating deck, located so as to provide lifting capabilities for all major vertical accessways and adjacent work areas. In addition, dedicated cranes will be provided for the maintenance hatch and reactor head service area.

Penetrations for Temporary Use

Section 4.3.4.10 of Chapter 6 states that a minimum of four normally sealed containment penetrations, at least 12 inches in diameter, will be provided near the maintenance hatch for routing temporary cable, piping, and hoses during outages to facilitate maintenance operations. In addition, four such penetrations will be provided at the operating deck level with at least two penetrations located to facilitate access for cables and hoses from the fuel building and storage facility. These penetrations will be sealed with blind flanges during normal operation.

Containment Elevator

Section 4.3.4.11 of Chapter 6 states that an elevator servicing all levels of the containment will be provided inside the containment and will be capable of carrying passengers and light freight.

The staff concludes that the requirements of Section 4.3.4 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.4 BWR Reactor Building and PWR Auxiliary Building

4.4.1 Introduction

Section 4.4 of Chapter 6 of the Evolutionary Requirements Document provides the requirements applicable to the BWR reactor building and the PWR auxiliary building.

4.4.2 BWR Reactor Building

Section 4.4.2 of Chapter 6 states that the BWR reactor building will contain the engineered safety systems, the reactor, the reactor coolant system, and non-safety-related auxiliary systems. It will surround, and be integral with, the primary containment. The reactor building surrounding the primary containment will serve as a secondary containment fission product leakage control (FPLC) boundary, and leak-tightness requirements will be established as necessary to meet the dose criteria in 10 CFR Part 100. Double doors and vestibules will be provided at entry areas that form part of the FPLC boundary. The access door for major equipment will be sized to accommodate the largest piece of equipment to be handled and will be located at grade level. A vertical hatchway will be provided over the staging area for moving loads between the upper floors and the access door. Cubicles located below grade will also have the necessary vertical hatchways and transport facilities. The reactor building will include rooms near the upper drywell hatch for the maintenance of safety-relief valves (SRVs) and main steam isolation valves (MSIVs) and rooms near the lower drywell hatch for servicing the reactor internal pumps and control rod drives. The building will have four elevators. A crane will be provided that will serve, as a minimum, the new fuel vault, the work end of the fuel pool, the equipment hatch, and the laydown areas. EPRI states that the crane will have sufficient capacity to lift the heaviest component in the building and will be able to lift a fuel cask. The main hoist will be single failure proof and meet ANSI/ASME NOG-1-1983 for Type I cranes. Interlocks will prevent the handling of heavy loads over the fuel storage pool.

To reduce personnel radiation exposure, "clean" and "controlled" areas will be segregated and personnel entry into the reactor building will be on the same level as the radioactive work change areas. Rooms will be provided in the reactor building so that SRVs and MSIVs can be serviced within the controlled zone without having to completely decontaminate them and move them out of the reactor building for servicing. The staff concludes that these features, which are intended to minimize personnel radiation exposure and to control the spread of contamination, are acceptable.

The staff concludes that the requirements of Section 4.4.2 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.4.3 PWR Auxiliary Building

Section 4.4.3 of Chapter 6 states that the PWR auxiliary building will contain the reactor auxiliary and safety systems that support the primary reactor systems. It will surround the primary containment. Access doors for major equipment will be located at plant grade and sized to accommodate the largest piece of equipment to be handled. Two elevators will be provided: one for clean areas and one for controlled areas. An emergency core cooling system (ECCS) equipment room will be located in each of the four building quadrants. One safety injection system train will be located in each quadrant. Two of the ECCS equipment rooms, located on opposite sides, will each house one of the two containment spray pumps. The other two opposite ECCS equipment rooms will each contain one of the two residual heat removal pumps. Flooding of one ECCS equipment room will not lead to flooding of another. The staff concludes that this separation should contribute to the reduction of threats from sabotage as well as fire compared to locating all redundant components of a system in the same room.

Section 4.4.3.3 of Chapter 6 states that the emergency feedwater (EFW) pump compartments will be located in the auxiliary building. The components will be arranged so that they will not be penetrated by main steamlines or main feedwater lines. Each of the four EFW pumps will be located in a separate compartment having separate access. Flooding of one EFW pump compartment will not lead to flooding of another EFW pump compartment. Compartments containing turbine-driven EFW pumps will be vented for protection against a steamline break and will be readily accessible for resetting the mechanical overspeed trip.

As discussed in Section 4.4.2 of this chapter, clean and controlled areas of the PWR auxiliary building will be segregated and personnel entry will be on the same level as the radioactive work change areas.

The staff concludes that the requirements of Section 4.4.3 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.5 Turbine-Generator Building

4.5.1 Definition and Scope

Section 4.5.1 of Chapter 6 of the Evolutionary Requirements Document states that the turbine-generator building will provide support and housing for the main turbine-generator and its auxiliary equipment, including the lube oil system, the hydrogen supply and cooling system, the stator cooling system, the seal oil system, the electrohydraulic control system, the generator exciter, and the gland steam sealing system as well as associated equipment such condensers, feedwater heaters, and condensate pumps.

4.5.2 General Requirements

Section 4.5.2 of Chapter 6 delineates the general design requirements for the turbine-generator building. Section 4.5.2.1 of Chapter 6 classifies the turbine-generator building as non-seismic Category I, in accordance with the definition in Regulatory Guide 1.29, "Seismic Design Classification," and requires that the building be designed, as a minimum, to the provisions of the Uniform Building Code. However, this seismic classification is not consistent with the classification in Section 4.3.2 of Chapter 1 of the Evolutionary Requirements Document. According to Section 4.3.2 of Chapter 1, the turbine building will be classified as either seismic Category II or non-seismic (NS) depending on whether or not the failure of the building structure during and after the safe shutdown earthquake (SSE) could impair the safety functions of any seismic Category I items. Therefore, the staff will review individual applications for FDA/DC to ensure that the turbine-generator building, at least for the BWR, is analyzed and designed to SSE loading conditions using the same criteria that are applicable for seismic Category I structures in accordance with the criteria of SRP Section 3.7.2 for interaction of non-Category I structures with Category I structures.

The turbine-generator building will be oriented so that any plane perpendicular to the turbine-generator axis will not intersect with the primary containment structure. Structural features will include (1) a steel or concrete, integrated or isolated, low-tuned turbine pedestal foundation; (2) a structural steel-supported operating floor; (3) precast walls; (4) reinforced-concrete shielding to the operating floor for a BWR design; (5) metal deck and steel beam construction instead of conventional forms and scaffolding; and (6) a metal siding enclosure in the absence of shielding requirements. Designated floor laydown areas will have the capacity to support heavy equipment.

4.5.3 Equipment Arrangement

Section 4.5.3 of Chapter 6 states that equipment will be physically and functionally arranged in accordance with the requirements of Chapter 2 of the Evolutionary Requirements Document. Access, rigging, and laydown features will be provided to facilitate maintenance. These features include the capability to remove all active components, a plant grade with a connection to a road or railway, main crane access to all major equipment or access to monorails or hoists to remove equipment to a central area, permanent platforms where practicable to provide easy access to key equipment, elevator service for all floors and main electrical areas, stairways at appropriate locations, provisions for maintenance of main condensers, placement of feedwater heaters to prevent turbine water induction from the heaters, accessibility of orifice plates for maintenance and inspection, accessibility of main steam reheaters and moisture separators for maintenance and repair, and provisions for heat exchanger retubing.

4.5.4 BWR Turbine-Generator Building

Section 4.5.4 of Chapter 6 states that the BWR turbine-generator building design will take into account the additional radiation effects of reactor steam that will be taken directly to the turbine building, including the effects of hydrogen injection for water chemistry control. Load-carrying walls and slabs will be used as shielding, and personnel access design requirements will be integrated with the site access plan. An off-gas recombiner will be provided in or near the turbine building and will be located to minimize the length of piping from the air ejectors to the recombiner.

EPRI states that the effects of hydrogen injection on nitrogen-16 levels will be considered in the design of the BWR turbine-generator building. Sufficient laydown space for maintenance of the turbine-generator and areas for decontaminating equipment and for cleaning filters will be provided. The staff concludes that these features, which are intended to maintain occupational exposure levels as low as is reasonably achievable (ALARA), are acceptable.

In letters dated May 17 and August 29, 1991, the staff requested that EPRI describe how the BWR main steamline beyond the seismic restraint up to and including the turbine stop valve, the turbine bypass lines to the condenser, and the condenser will be protected from the possible failure of non-seismic Category I structures, components, and systems during a postulated SSE. EPRI responded to these requests in a letter dated November 6, 1991. The staff's evaluation of the turbine-generator building is provided in Appendix B to Chapter 1 and Chapters 3, 5, and 13 of this report.

4.5.5 Conclusion

The staff concludes that the requirements of Section 4.5 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.6 Other Power Generation Complex Facilities

4.6.1 Definition

The power generation complex (PGC), as defined by EPRI, will include other facilities, either as separate buildings or as an integral part of the auxiliary building (PWR) or reactor building (BWR) structure. These facilities are discussed in Sections 4.6.2 through 4.6.6 below.

4.6.2 Fuel Handling and Storage Facility

Section 4.6.2 of Chapter 6 of the Evolutionary Requirements Document states that the fuel handling and storage facility will include all the facilities for the handling, storage, and inspection of new and irradiated fuel; the inspection and repair of fuel assemblies; and the transfer of new and irradiated fuel. Requirements for fueling and refueling systems and equipment are given in Chapter 7 of the Evolutionary Requirements Document and are evaluated by the staff in Chapter 7 of this report. The requirements of Section 4.6.2 of Chapter 6 apply to building structural design and arrangement. For BWRs, the fuel facility will be located in the reactor building on the operating deck level. For PWRs, it will be located adjacent to the auxiliary building on the side opposite the turbine building.

Section 4.6.2.3 states that the general structural and loading requirements are specified in Section 4 of Chapter 1.

Section 4.6.2.4.2 of Chapter 6 states that new fuel will be stored in a dry vault. The vault will be designed so that it will be impossible to achieve criticality in the dry vault, even if it were to be flooded with unborated water. The capacity of the new fuel storage vault will be 40 percent of a full core for BWRs and 66.7 percent for PWRs, based on the fuel required for two refuelings.

Section 4.6.2.4.4 of Chapter 6 states that the design and arrangement of the fuel handling and storage facilities will preclude the transport of spent fuel shipping casks over the fuel storage pool or safety-related equipment. The cask pool will be located next to the storage pool and will be connected to it by a canal containing a watertight gate. The bottom of the canal will be at an elevation above the top of the storage racks. For the PWR and BWR design, the cask cannot drop more than the distance equal to the structural limit of the cask pool bottom in a drop accident, and the fuel pool will be designed to preclude the loss of fuel cooling or of safe-shutdown capability in the event of a cask drop in the cask pool.

Section 4.6.2.4.5 of Chapter 6 states that the layout and arrangement will permit major heavy lifts to be accomplished in one lift without the need to lay down the transported item at an intermediate location.

Section 4.6.2.4.6 of Chapter 6 states that the fuel storage and handling facility will be designed to accommodate the fuel-handling accident described in Chapter 7 of the Evolutionary Requirements Document.

Section 4.6.2.4.8 of Chapter 6 states that a pad for washing down a fuel cask and a truck or railcar will be provided outside the building. An area adjacent to the cask pool will be provided for the preparation, decontamination, and testing of casks.

The staff's evaluation of the fueling and refueling facilities is provided in Chapter 7 of this report.

4.6.3 Radwaste Facility

Section 4.6.3 of Chapter 6 specifies the arrangement requirements applicable to the radwaste facility. System requirements are given in Chapter 12 of the Evolutionary Requirements Document and are evaluated by the staff in Chapter 12 of this report.

Section 4.6.3.3 of Chapter 6 requires that the radwaste building design and equipment structural supports meet the guidelines of Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," and that the building design meet American Concrete Institute 318, "Building Code Requirements for Reinforced Concrete," and the requirements of the American Institute of Steel Construction. The staff concludes that this requirement is acceptable.

Radwaste facilities will be located as depicted in the general plot plans and arrangement sketches in the appendices to Chapter 6 of the Evolutionary Requirements Document.

The radwaste facility will be designed so that contamination of the waste transport truck is precluded and the expected doses to truck drivers will be comparable to background levels. Radwaste piping carrying fluids with high-solids content will be designed to minimize the potential for plugging by the use of short runs and long radius bends. Provisions for automatic flushing after each use will be provided for this piping.

To maintain doses to radwaste operators as low as is reasonably achievable (ALARA), EPRI requires that special radwaste-handling methods, including the use of robotics, local lifting equipment, shielding bells, and automatic equipment, be used in the radwaste facility. In addition, all access halls and the radwaste control station will be located in low-radiation zones. The staff concludes that the above design features for the radwaste facility comply with the guidelines of Regulatory Guide 8.8 for maintaining occupational exposures ALARA and are acceptable.

The staff concludes that the requirements of Section 4.6.3 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.6.4 Emergency Onsite Power Supply Facility

The staff's evaluation of the emergency generator system is given in Chapter 11 of this report. The BWR design specifies three emergency generators; the PWR design specifies two. The generators, each within its own compartment, will be located in seismic Category I structures. The emergency generator system in a BWR will be located in the reactor building.

Section 4.6.4.2 of Chapter 6 states that compartment design and separation will be such that an explosion or fire in one emergency generator compartment will not disable another. Each generator will have independent, dedicated support systems. It will be possible to remove and replace a generator without affecting the operability of another generator and without destructive removal of walls. The tanks will be capable of being tested for water and of being drained of water. The fuel service systems will be provided with sampling capability throughout.

Communication capability will be provided between the control room and the emergency generator compartments. The generator compartments will also be provided with crane facilities, access space, and laydown space to permit major repairs.

Fuel storage tanks will be located as described in Section 2.3 of Chapter 6.

The staff concludes that the requirements of Section 4.6.4 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.6.5 Control Complex

The control complex will include the main control room, that is, the "control room emergency zone," as defined by SRP Section 6.4, "Control Room Habitability Systems," and other rooms that support the main control room operations. These other rooms include cable spreading rooms, computer and equipment rooms, and may include such rooms as offices, instrument shops, and the technical support center. Man-machine interface systems are described in Chapter 10 of the Evolutionary Requirements Document and are evaluated by the staff in Chapter 10 of this report

Location

In the DSER for Chapter 6, Section 4.6.5.2, the staff stated that EPRI was evaluating the location of the control complex between the auxiliary building (PWR) or the reactor building (BWR) and the turbine building. Because EPRI had not settled on a final location, this was identified as an open issue.

Section 4.6.5.2 of Chapter 6 has been revised to require that the general location of the control complex be between the reactor building and the turbine-generator building. It may be located in a separate building or it may be part of another seismic Category I building. EPRI states that the location of the control complex between the nuclear steam supply system components and the balance-of-plant components will facilitate separation of redundant divisions of electrical power and control cables. This central location is also consistent with the main control room's function as the h[illegible] of the plant operating staff's activities.

The objective of the control room is to ensure that plant operators are protected against the effects of accidental releases of toxic and radioactive gases and that the control room can be maintained as the backup center from which technical support center personnel can safely operate in case of an accident. Therefore, the control complex air inlets should be located taking into consideration the potential release points of radioactive material and toxic gases. The guidance and acceptance criteria for the control room habitability system design are provided in SRP Section 6.4 and the specific general design criteria and regulatory guides addressed in the SRP. However the NRC has no regulatory requirements for the location of the control complex relative to other buildings. The staff concludes that EPRI's requirements for the location of the control complex are acceptable, provided the control complex design meets SRP Section 6.4. Therefore, this DSER open issue is closed.

HVAC Design

Section 4.6.5.4.1 of Chapter 6 states that the control room ventilation system is safety related and the system will meet the single-failure criterion. Air intakes will be located and protected to preclude the intake of other than fresh air. Control room doors and penetrations will be designed to exclude smoke, steam, water, and firefighting chemicals applied to areas outside the control room.

The staff concludes that, for some facilities, it may be necessary to have two remote ventilation air intakes in order to meet the dose criteria of General Design Criterion 19 of 10 CFR Part 50, Appendix A. The staff will review this item on a design-specific basis during its review of an individual application for FDA/DC.

Control Room Emergency Zone

In the DSER for Chapter 6, the staff stated that the spaces in the control room emergency zone designated in Section 4.6.5.4.2 of Chapter 6 were inconsistent with those of the control room envelope defined in Section 8.2.2.1 of Chapter 9, in that the computer room was included in the control room emergency zone but not in the control room envelope. The staff stated that EPRI should resolve this discrepancy and identified this issue as an open issue.

Section 8.2.2 of Chapter 9 has been revised to state that the control complex will include the main control room envelop, computer, essential switchgear, battery rooms, and HVAC equipment room. EPRI also revised Section 4.6.5.4.2 of Chapter 6 to replace "envelope" with "emergency zone" and to include the computer room in the control room emergency zone. EPRI stated that the control complex is intended to include more than the control room itself and it will be composed of several separate fire areas. Therefore, the terminology in Chapter 6 is consistent with SRP Section 6.4.

Branch Technical Position (BTP) CMEB 9.5-1 (SRP Section 9.5.1) states that the control room complex is the zone served by the control room emergency ventilation system and includes the control room, computer room, shift supervisor's office, and operator wash room and kitchen. The staff concludes that the EPRI requirements for the design of the ALWR control complex meet the guidance of SRP Section 6.4 and BTP CMEB 9.5-1, and that there is no longer a discrepancy between Chapter 6 and Chapter 9 of the Evolutionary Requirements Document. Therefore, this DSER open issue is closed.

Human Factors

Section 4.6.5.4.2 of Chapter 6 states that a control room emergency zone encompassing the control room, critical documents file, computer room, shift supervisor's office, lavatory, kitchen and eating area, and other areas requiring continuous or frequent occupancy under accident conditions will be provided in ALWR designs. The zone will be designed in accordance with human factors guidelines to facilitate operability and to maintain habitability during upset conditions. In the DSER for Chapter 6, the staff stated that it had requested that EPRI provide additional information on the requirements and acceptance criteria for human factors considerations to ensure that operability and maintainability are achieved in building arrangements. This was identified as an open issue in the DSER. The staff has evaluated EPRI's requirements for human factors considerations in Chapter 10 of this report. Therefore, this DSER open issue is closed.

Conclusion

The staff concludes that the requirements of Section 4.6.5 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification or alternative means of implementing the associated regulatory requirements.

4.6.6 Technical Support Center

Section 4.6.6 of Chapter 6 states that the technical support center (TSC) will be located so that it is convenient to the control room. EPRI states that the TSC will meet the criteria in NUREG-0696, "Functional Criteria for Emergency Response Facilities." The TSC HVAC system will be independent of that of the control room envelope. It will be non-safety grade, functionally similar to that of the control room envelope, and provided with high-efficiency particulate air filters.

The staff concludes that the requirements of Section 4.6.6 of Chapter 6 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

5 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 6 of the Evolutionary Requirements Document for building design and arrangement do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the plant-specific building design and arrangement will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the Standard Review Plan (SRP) (NUREG-0800), or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 6 of the Evolutionary Requirements Document specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose building design and arrangement are such that there will be no undue risk to the health and safety of the public or to the environment. In addition to complying with existing regulations, such a facility would also be consistent with Commission policies on severe-accident protection.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 6 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
GENERIC SAFETY AND LICENSING ISSUES

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address the resolution of generic safety issues in Appendix B of each chapter. In the DSER for Chapter 6 of the Evolutionary Requirements Document, the staff evaluated EPRI's requirements to address the resolution of the following generic safety issues:

- 103, "Design for Maximum Probable Precipitation"
- 118, "Tendon Anchorage Failures"

In Revision 1 of the Evolutionary Requirements Document, submitted by letter dated September 7, 1990, EPRI relocated its requirements to address generic safety issues that were unresolved as of January 1, 1990, to Appendix B to Chapter 1. As a result, a number of generic safety issues that were addressed in the original Evolutionary Requirements Document are no longer addressed. The staff has provided its evaluation of EPRI's requirements to address generic safety issues in Appendix B to Chapter 1 of this report. The staff has also documented its closure of DSER open and confirmatory issues associated with generic issues no longer addressed by EPRI in Appendix B to Chapter 1 of this report. Therefore, the DSER confirmatory issue associated with Generic Issue 103 is closed.

APPENDIX C
BWR CONSTRUCTION PLAN AND ARRANGEMENT SKETCHES

Appendix C to Chapter 6 of the original version of the Evolutionary Requirements Document contained a construction schedule for a BWR. The schedule provided for a 54-month construction period (first concrete to warranty demonstration). Preliminary plant arrangement drawings were also included. Because of the relocation of EPRI's requirements to address the resolution of unresolved safety issues and generic safety issues to Appendix B to Chapter 1, EPRI's original Appendix C to Chapter 6 has been redesignated as Appendix B.

The staff concludes that the requirements of redesignated Appendix B to Chapter 6 of the Evolutionary Requirements Document do not conflict with current regulatory guidelines.

APPENDIX D
PWR CONSTRUCTION PLAN AND ARRANGEMENT SKETCHES

Appendix D to Chapter 6 of the original version of the Evolutionary Requirements Document contained a construction schedule for a PWR. The schedule provided for a 54-month construction period (first concrete to warranty demonstration). Preliminary plant arrangement drawings were also included. Because of the relocation of EPRI's requirements to address the resolution of unresolved safety issues and generic safety issues to Appendix B to Chapter 1, EPRI's original Appendix D to Chapter 6 has been redesignated as Appendix C.

The staff concludes that the requirements of redesigned Appendix C to Chapter 6 of the Evolutionary Requirements Document do not conflict with current regulatory guidelines.

APPENDIX E
MAINTAINABILITY EVALUATION

Appendix E to Chapter 6 of the original version of the Evolutionary Requirements Document provided a sample format for the report of an evaluation demonstrating that maintenance access and planning requirements of the Evolutionary Requirements Document will be met. The purpose of the evaluation, which will be performed by the plant designer, is to ensure the following:

- Refueling can be completed in 17 days.
- Satisfactory services can be provided at the access control facility.
- Critical maintenance tasks can be performed easily and quickly.
- Access to all components is available for their removal and replacement, and these components can be transported using safe, preplanned lifting and transport methods.

Included in this appendix are (1) a list of critical maintenance tasks to be evaluated, (2) a sample maintenance task checklist, (3) a sample transport task checklist, and (4) a sample evaluation of a critical maintenance task. The evaluations described by this appendix are intended to demonstrate that the completed standard plant arrangement under review will facilitate performing the tasks identified in Section 8 of Chapter 1 of the Evolutionary Requirements Document. The tasks referenced in Section 8 of Chapter 1 are those that have historically contributed to extended outages, large percentages of total plant person-rem exposure, and excessive efforts to improve maintainability through plant modifications.

Because of the relocation of EPRI's requirements to address the resolution of unresolved safety issues and generic safety issues to Appendix B to Chapter 1, EPRI's original Appendix E to Chapter 6 has been redesignated as Appendix D. Although the information in redesignated Appendix D to Chapter 6 of the Evolutionary Requirements Document is not subject to SRP review criteria, the staff concludes that it does not conflict with current regulatory guidelines. However, an FDA/DC or combined license applicant should explicitly state that plant safety will not be compromised in attempting to satisfy refueling, critical maintenance tasks, and other requirements addressed in Appendix D.

CHAPTER 7, "FUELING AND REFUELING SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 7, "Fueling and Refueling Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 7 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering Nuclear Power; Commonwealth Edison Company; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Westinghouse Electric Corporation; Yankee Atomic Electric Company; and EPRI.

On February 28, 1989, EPRI submitted Chapter 7 of the Evolutionary Requirements Document for staff review. By letters dated April 28, May 24, and July 14, 1989, and July 18, 1990, the staff requested that EPRI supply additional information. EPRI provided the information in its responses dated August 18, September 15, and December 22, 1989, and January 18, 1990.

On January 15, 1991, the staff issued its DSER for Chapter 7 of the Evolutionary Requirements Document. On April 9, 1991, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 7, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 7, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1, of this report describes the approach and review criteria used by the staff during its review of Chapter 7 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 7

Chapter 7 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the fueling and refueling systems.

The key topics addressed in the Chapter 7 review include EPRI-proposed design requirements for

- spent fuel pool
- fuel pool cooling and cleanup system
- new fuel storage facility
- cask receiving and handling facilities
- fuel handling system
- other related systems and equipment

1.3 Policy Issues

During its review of Chapter 7 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 7 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) human factors considerations (2)
(2) radiological consequences of fuel handling accident (3.2.2)
(3) criticality of new fuel in new fuel storage facility (5)
(4) radiological consequences of fuel cask drop accident (6.5)
(5) safety classification of the refueling platform assembly (7.1.2)
(6) high-radiation areas (7.2)
(7) segregation of fuel pool area used for fuel reconstitution (7.4)
(8) Generic Safety Issue 82 (Appendix B)

Confirmatory Issue

(1) quality group classification of components for new and spent fuel storage racks (3.2.1 and 5)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All outstanding issues identified in the DSER for Chapter 7 of the Evolutionary Requirements Document have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.7.V-1 quality group classification of components for new and spent fuel storage racks (3.2.1)
E.7.V-2 radiological consequences of fuel handling accident (3.2.2)
E.7.V-3 protection against tampering during refueling activities (3.2.4)
E.7.V-4 design of the overhead bridge crane (6.1.2)
E.7.V-5 radiological consequences of fuel cask drop accident (6.5)
E.7.V-6 design of the fuel handling system (7.1.2)
E.7.V-7 reactor disassembly and servicing equipment for BWRs (7.5)

2 GENERAL REQUIREMENTS AND POLICY STATEMENTS

The fueling and refueling systems will include all the facilities for the safe handling and inspection of new fuel, the storage of new and spent fuel, the inspection and repair of spent fuel bundles, and the transfer of new and spent fuel. The structural design requirements for these systems are provided in Chapter 1 of the Evolutionary Requirements Document. The staff's evaluation of these requirements is provided in Chapter 1 of this report.

Sections 1.5.2 and 2.2.1 of Chapter 7 of the Evolutionary Requirements Document state that the ALWR fueling and refueling systems will be designed so that the reactor can be refueled in 17 calendar days or less. This assumes a 24-month plant operating cycle, which requires the replacement of more fuel assemblies than a 12- or an 18-month cycle. The tasks assumed for the 17-day refueling outage are only those tasks that must be performed each time the reactor is refueled. Additional outage time over plant life is allowed for performing other tasks that are not required each time the reactor is refueled. Also, the Evolutionary Requirements Document assumes that all plant equipment that is shared for performing activities that are not related to refueling during the outage will be available whenever needed so that no delay is encountered because of competing use.

One of the objectives of going to a 17-day (maximum) refueling outage is to reduce the amount of personnel exposure associated with refueling operations. In recent years, refueling operations have accounted for between 6 and 8 percent of the total annual plant collective dose. EPRI expects that the criteria in Chapter 7 will result in lower doses associated with refueling by permitting fueling and refueling operations to be performed more expeditiously through the use of more automatic or remote control processes. Some of the design criteria specified by EPRI to lower doses include the use of permanent refueling seals, the use of integrated head removal features, and the specification of smooth surface conditions on pool walls to facilitate decontamination.

Section 1.5.6 of Chapter 7 states that the chapter includes man-machine interface requirements specific to fueling and refueling equipment. The goal of this chapter, as stated by EPRI, is to eliminate the man-machine interface problems that have existed in the design of past and current refueling equipment by emphasizing features that simplify the interaction of the operator with the principal operating equipment. In its letter dated August 30, 1990, the staff requested additional information regarding EPRI's approach to incorporating human factors considerations into the Evolutionary Requirements Document. Because it had not completed its review, the staff identified this as an open issue in the DSER for Chapter 7. The staff's evaluation of EPRI's requirements to human factors considerations associated with fueling and refueling systems is provided in Section 3.7.6 of Chapter 10 of this report. Therefore, this DSER open issue is closed.

Section 1.5.7 of Chapter 7 describes two different approaches for handling spent fuel and spent fuel casks: the shuttle method and the cask immersion method. The staff discusses these approaches further in Section 6.2 of this chapter.

Section 1.5.10 of Chapter 7 states that the ALWR will be designed to minimize the potential for an inadvertent refueling pool draindown event. The staff discusses this event in Section 3.2.4 of this chapter.

3 SPENT FUEL POOL

3.1 Functions and Key Design Requirements

Section 1.3.1 of Chapter 7 of the Evolutionary Requirements Document states that the principal functions of the spent fuel pool, including the spent fuel racks, are the following:

- Provides storage for a full core off-load and for spent fuel assemblies until the decay heat and radiation generated by the assembly are acceptably low for shipment of the assembly off site or for its transfer to onsite dry storage facilities. It also provides storage for other irradiated reactor core components awaiting shipment for disposal off site.

- Provides a means for removing the decay heat generated by the spent fuel in the pool and maintains temperatures of the fuel rods well below temperatures at which the cladding could melt or the fuel could be damaged in any way.

- Safely stores spent fuel assemblies in subcritical arrays.

- Protects personnel by providing shielding against the radiation generated by the stored spent fuel assemblies.

- Provides space for the reconstitution, repair, and inspections of fuel assemblies and for the consolidation of fuel rods.

- Provides a sufficient volume of water to ensure adequate cooling of the spent fuel assemblies and shielding of personnel during a station blackout.

- Provides a fission-product scrub to reduce the radioactivity of iodine released from the pool.

The key design requirements in Chapter 7 for the spent fuel storage pool include the following:

- The spent fuel storage facility will accommodate spent fuel resulting from 10 calendar years of plant operation plus the total number of assemblies in one core.

- The pool will be big enough so that there will be at least 10 feet of water left above the fuel assemblies after 8 hours of loss of cooling, assuming the maximum permissible fuel load.

- The pool will be provided with a leaktight 1/4-inch austenitic stainless steel liner plate of welded construction.

- All the materials used in pool construction will be compatible with a borated water environment.

- The fixed neutron absorber, which is specified as an option for "high-density" fuel storage racks in the pool, will be of such a type that mechanical distortion and chemical degradation will be precluded.

- The pool will be designed to accommodate 170 percent of the core (BWR) or 333 percent of the core (PWR) for spent fuel discharged in batches during the normal refueling cycle plus 100 percent removed from the core at its maximum level of exposure before refueling. In addition, space will be provided for storing a full set of control rods, fuel channels, equipment for inspecting fuel and channels, and leak-testing equipment.

- The spent fuel storage racks will be designed to be freestanding (without lateral support from walls or anchorage to the floor), to be stable for all conditions of rack fill and seismic loading, and to ensure that a fuel assembly cannot be inserted anywhere other than in a design location. In addition, they will be designed to withstand, without compromising the integrity of the fuel rod cladding of the stored fuel assemblies, the impact resulting from a falling fuel assembly, including a control rod insert (PWR only), a falling fuel-handling tool, and a hoist box or mast assembly dropped from the highest elevation possible under normal loading and unloading conditions.

- Anti-siphon provisions will be included in the design of the fuel pool cooling and cleanup system piping to prevent the drainage of the spent fuel pool as a result of the drainage of piping or components in the system.

- Drains or permanently connected mechanical or fluid systems whose failure could cause sufficient loss of coolant to reduce water coverage over the stored fuel assemblies to less than 10 feet will not be installed or included in the pool design.

- The pool liner seam welds will be equipped with a continuous drainage system that is monitored to detect leakage through the liner.

- Instrumentation will be provided to alarm in the control room if the level in the spent fuel pool drops below a predetermined value.

3.2 Evaluation

3.2.1 Quality Group Classification

Sections 2.3.1 and 2.3.3.2 of Chapter 7 of the Evolutionary Requirements Document respectively state that the requirements in American National Standards Institute/American Nuclear Society (ANSI/ANS) 57.2, "Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants," and 57.3, "Design Requirements for New Fuel Storage Facilities at Light Water Reactor Plants," should be considered in the design of all systems and equipment that are associated with the storage of spent and new fuel. For the safety classification of these components, systems, and equipment, ANSI/ANS 57.2 and 57.3 both reference ANSI/ANS 51.1, "Nuclear Safety Criteria for the Design of Stationary PWR Plants," and ANSI/ANS 52.1, "Nuclear Safety Criteria for the Design of Stationary BWR Plants." ANSI/ANS 51.1 and 52.1 contain the following classification: "New and spent fuel storage racks are classified as seismic Category I but are not required to conform to the quality assurance requirements of 10 CFR Part 50, Appendix B." As discussed in Section 4.3.1 of Chapter 1 of this report, the staff has not completely endorsed these two standards. The staff's position on this issue, as stated in the DSER for Chapter 7, is that the new and spent fuel storage racks for both BWRs and PWRs should be designed, fabricated, constructed, and tested in accordance with the applicable quality assurance requirements of 10 CFR Part 50, Appendix B, in addition to being classified as seismic Category I.

In a letter dated December 22, 1989, in response to a staff request for information dated September 14, 1989, EPRI stated that 10 CFR Part 50, Appendix B, was applicable to both new and spent fuel storage racks. In its response, EPRI also stated that Chapter 7 would be modified to clarify this position. This issue was identified as a confirmatory issue in the DSER.

EPRI has revised the Evolutionary Requirements Document to address this issue by including a commitment to meet Regulatory Guide (RG) 1.29, "Seismic Design Classification," in Table B.1-2 of Appendix B to Chapter 1. RG 1.29, in turn, specifies the requirements of Appendix B to 10 CFR Part 50. Also, there is a specific requirement in Chapter 1, Section 4.3.2.1, of the Evolutionary Requirements Document that all fuel racks be seismic Category I. The staff concludes that this requirement, together with the commitment in Table B.1-2 to meet the requirements of 10 CFR Part 50, Appendix B, provides acceptable seismic and quality assurance requirements for the new and spent fuel storage racks. Therefore, the staff will review individual applications for FDA/DC in accordance with these commitments, and this DSER confirmatory issue is closed.

3.2.2 Accident Analysis - Fuel Handling Accident

In the DSER for Chapter 7, the staff noted that EPRI had provided an accident analysis for the fuel handling accident covered in Chapter 7 of the Evolutionary Requirements Document. The staff concluded that the Evolutionary Requirements Document should address and specify the ALWR design requirements to mitigate the radiological consequences of a postulated fuel handling accident during which an object is dropped onto irradiated fuel resulting in the release of fission products from the stored fuel. The staff stated that EPRI should establish the source term for a fuel handling accident at an ALWR plant including, but not limited to, (1) the minimum fuel pool water depth for scrubbing airborne radioactive material released from the damaged fuel in the spent fuel pool, (2) the closure time for the containment purge valve and vent valve, and (3) the iodine removal efficiency for the fuel handling heating, ventilation, and air conditioning system. This was identified as an open issue in the DSER.

EPRI revised Table B.1-2 of Appendix B to Chapter 1 to require that ALWRs meet the guidance in Regulatory Guides 1.13, "Spent Fuel Storage Facility Design Basis," and 1.25, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors." Regulatory Guide 1.13 requires the plant to be designed taking into consideration fuel handling accidents, and Regulatory Guide 1.25 provides assumptions and parameters that should be used when evaluating radiological consequences of a fuel handling accident. This is in accordance with the guidance in SRP Section 15.7.4, "Radiological Consequences of Fuel Handling Accidents," and is acceptable. Therefore, this DSER open issue is closed. Because EPRI further stated that specific details of how the plant design will satisfy the regulatory guide requirements were beyond the level of detail typically provided in the Evolutionary Requirements Document, the staff will review these details during its review of an application for a FDA/DC.

3.2.3 Occupational Exposure

SRP Section 12.3, "Radiation Protection Design Features," states that areas that are occupied on a predictable basis during anticipated operational occurrences (such as refuelings) should be zoned so that this occupancy results in an annual dose to each of the involved individuals that is as far below the limits of 10 CFR Part 20 as is reasonably achievable. Section 2.3.1.1.1 of Chapter 7 of the Evolutionary Requirements Document states that the spent fuel pool should be designed so that the necessary water depth is maintained above the top of the spent fuel assemblies to ensure that the exposure rate to personnel on the spent fuel pool refueling machine will be less than 2-1/2 mrem/hour. This limit is consistent with ANSI/ANS 57.2 and 10 CFR Part 20 and is acceptable.

The Evolutionary Requirements Document specifies several design features to prevent the partial draining of the fuel pool and the resulting increase in dose rates in the refueling area. In several instances, fuel pools have been partially drained as a result of component failure (such as failure of the transfer canal seal) or improper valve lineup. Section 2.3.1.1.3 of Chapter 7 states that the seal design for the spent fuel gates will be such that a seal or pneumatic system failure will not cause the seal to displace from the seal cavity (thereby potentially resulting in a partial draining of the pool). In addition, the pool design will not include any drains or permanently connected mechanical or fluid systems whose failure would result in a loss of fuel pool water.

To prevent the existence of harsh radiological environments above the spent fuel pool, Section 2.3.1.1.1 of Chapter 7 states that radioactive non-fuel components in the spent fuel pool will be "handled" and "stored" (when not being used) below the normal minimum required water shielding depth. Section 2.3.1.2 of Chapter 7 states that fuel pool storage rack locations where the storage of spent fuel could present a radiation hazard to personnel or could otherwise restrict access to adjacent locations will not be included in future fuel pool designs. If the pool design includes such storage rack locations, their restricted use will be clearly identified. The staff concludes that these requirements are acceptable because they serve to minimize personnel exposures and are in compliance with the guidelines of Regulatory Guide 8.8, "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable."

The EPRI criteria for the refueling area include several design features for ensuring that occupational exposures are maintained as low as is reasonably achievable. Section 2.3.1.1.7 of Chapter 7 states that long-life bulbs will be used in radiation areas to reduce the frequency of personnel entries into the areas to replace burned-out bulbs. The spent fuel racks will be designed so that the spent fuel pool floor under the racks can be vacuumed to prevent the buildup of radioactivity in the pool water. Section 2.3.1.3 states that the surface of the refueling pool wall liner will have a smooth finish to reduce the adherence of contamination and to facilitate decontamination of the liner. Section 2.3.1.3 also states that a sparger system will be provided around the perimeter of the refueling pool to keep the walls wet when the pool is being flooded or drained to reduce airborne contamination. These features are consistent with the guidelines of Regulatory Guide 8.8 and are acceptable.

3.2.4 Sabotage Protection Against Refueling Pool Draining

Section 1.5.10 of Chapter 7 of the Evolutionary Requirements Document states that the document includes requirements to preclude draining of the fuel pool as a result of equipment failure or siphoning.

In its letter dated August 18, 1989, EPRI stated: "Even though the ALWR plant arrangements currently show the spent fuel pool walls as interior walls, there is insufficient basis to make this a requirement, particularly in view of their inherent massiveness compared to other plant structures."

The staff considers that the spent fuel pool walls are massive enough that a requirement that they be located away from the exterior is not warranted. The staff concludes that LWR designers should evaluate the measures (e.g., having inflated seals cover only a narrow gap and using bolted steam generator dams) to reduce the opportunities for draining fuel transfer canals during fuel transfer. The staff will evaluate design considerations given to protection against tampering during refueling activities during its review of an individual application for FDA/DC.

3.2.5 Conclusion

The staff concludes that the design requirements in Chapter 7 of the Evolutionary Requirements Document for the spent fuel pool are consistent with the guidance in SRP Section 9.1.2, "Spent Fuel Storage," and are, therefore, acceptable.

4 FUEL POOL COOLING AND CLEANUP SYSTEM

4.1 Functions and Operating Modes

The Evolutionary Requirements Document contains specific requirements for the removal of the decay heat generated by the spent fuel and for maintaining high purity of water in the spent fuel pool. It specifies dedicated systems for performing these functions. Chapter 7 of the Evolutionary Requirements Document states that these systems will

- maintain spent fuel temperature within acceptable limits
- ensure that there is enough water inventory in the pool so that all the spent fuel assemblies will remain properly immersed
- maintain water quality in the spent fuel pool

Section 2.2.3.4 of Chapter 7 states that the design of the systems will permit them to operate in the following modes:

- cooling and cleanup of the spent fuel pool
- cleanup of the in-containment refueling water storage tank (PWR) or the suppression pool (BWR)
- cleanup of the refueling pool
- cleanup of the cask loading pit
- cooling and cleanup of the spent fuel pool simultaneously with one other element of the system
- skimming of the spent and/or refueling pool
- cooling of the spent fuel pool under limiting emergency conditions of single-system failure
- makeup of spent fuel pool inventory

These modes of operation cover the operational requirements in SRP Section 9.1.3, "Spent Fuel Pool Cooling and Cleanup System." Section 2.2.2.3 of Chapter 7 of the Evolutionary Requirements Document provides detailed specifications for system performance. It requires that the water temperature in the pool be maintained at or below 140 °F with a maximum fuel load. For a normal expected fuel load, EPRI states that this temperature limit should not be exceeded even with a single active failure of the system. However, for a maximum load with a single failure, the Evolutionary Requirements Document specifies a temperature limit of 180 °F, which is still below the boiling point of water.

4.2 Evaluation

The Evolutionary Requirements Document specifies that the water in the pool should be clear enough so that the spent fuel immersed in the pool will be clearly visible to the operator. To achieve that goal and to prevent materials coming in contact with water from becoming corroded, the chemistry of the pool water must be rigorously controlled. Also, the potential sources of contamination should be reduced to a minimum. Section 2.2.3.2 of Chapter 7 of the Evolutionary Requirements Document recommends that EPRI NP-1081, "Refueling Outage Water Clarity Improvement Study," be used as guidance. All these specifications and recommendations comply with SRP Section 9.1.3 and are, therefore, acceptable.

To maintain the water clarity needed for refueling operations, the Evolutionary Requirements Document states that operators may use instruments such as underwater binoculars, floating view plates, and optical fiber viewing devices. Section 2.2.3.6 of Chapter 7 states that skimmers, or an equivalent system, will be provided at the periphery of the spent fuel pool and refueling pool to remove foreign material from the water surface, thereby improving water clarity. Skimmers will also serve to reduce the extent of airborne contamination. By improving water clarity, refueling operations can be accomplished more expeditiously, thereby reducing the doses received by refueling personnel. The staff concludes that these features are acceptable.

Additional requirements that address the fuel pool cooling and cleanup system are provided in Chapter 8 of the Evolutionary Requirements Document. The staff's evaluation of these additional requirements is provided in Chapter 8 of this report.

5 NEW FUEL STORAGE FACILITY

Storage Capacity

Section 2.2.5 of Chapter 7 of the Evolutionary Requirements Document states that the new fuel storage facility will provide onsite dry storage for the normal number of new fuel assemblies replaced each refueling outage for a 24-month cycle. This requirement will ensure that after the initial core load, new fuel will not need to be stored in the spent fuel pool. Section 2.3.3.2 states that the new fuel storage facility will be designed so that a fuel assembly cannot be inserted anywhere in the racks other than in the design locations. Provisions are to be made for draining the vault to prevent the accumulation of a fluid moderator.

Criticality

Section 2.2.5 of Chapter 7 requires that the new fuel storage facility be designed so that subcriticality (K_{eff} of less than 0.95) is maintained for fresh fuel under all plant conditions, including flooding. In the DSER for Chapter 7, the staff stated that other overmoderated conditions, not just flooding, could occur in the new fuel storage facility as a result of, for example, the actuation of fire suppression systems. The staff concluded that the Evolutionary Requirements Document should be modified to stipulate that subcriticality will be maintained under all plant conditions, including foam, mists and sprays, and flooding and identified this as an open issue. In response to the DSER, EPRI revised the nuclear design requirements for the new fuel storage facility. Section 2.2.5.2 of Chapter 7 now states that, as a goal, the new fuel storage facility will be designed so that K_{eff} of no greater than 0.95 is maintained for fresh fuel under optimum moderator conditions. However, under no conditions will K_{eff} be greater than 0.98. The staff concludes that this is consistent with the criteria in SRP Section 9.1.2, "Spent Fuel Storage," and is, therefore, acceptable. This DSER open issue is closed.

Quality Classification

As stated by the staff in Section 3.2.1 of this chapter, EPRI's original position was that new and spent fuel storage racks need not comply with the requirements of 10 CFR Part 50, Appendix B. The staff disagrees. Its position on the classification of the new and spent fuel storage racks for both PWRs and BWRs is that they should be designed, fabricated, constructed, and tested in accordance with the quality assurance requirements of 10 CFR Part 50, Appendix B, in addition to being classified as seismic Category I.

Section 3.2.1 of this chapter presents the staff's evaluation of the seismic and quality assurance requirements for new fuel storage racks.

Conclusion

The staff concludes that the design requirements in Chapter 7 of the Evolutionary Requirements Document for the new fuel storage facility are consistent with the guidance in SRP Section 9.1.1, "New Fuel Storage," and are, therefore, acceptable.

6 CASK RECEIVING AND HANDLING FACILITIES

6.1 Heavy Loads Considerations

6.1.1 Key Design Requirements

Section 2.3.1.1.4.2 requires that the plant design must ensure the safe handling of heavy loads around the reactor vessel and the spent fuel pool and, as a minimum, must meet the provisions of NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants." Section 2.3.2.3 of Chapter 7 of the Evolutionary Requirements Document specifies that an overhead bridge crane rated for no less than 150 tons will be provided for handling casks. Additional key requirements in this Section 2.3.2.3 include the following:

- The crane traveling range and building will be arranged so that the cask, if dropped in any location along its path, cannot damage new or spent fuel, cannot result in the drainage of the spent fuel pool, and cannot damage any safety-related system or structure, and that the cask itself will not fall in a manner that will result in significant offsite consequences. For the BWR only, if the plant design precludes the use of a separate cask loading pit, a single-failure-proof crane may be used to reduce the probability of a drop along the cask's travel path. However, even for a single-failure-proof crane, interlocks will be used to prevent heavy loads from traveling over the spent fuel pool.

- The overhead crane that will serve the facility where casks will be received will be provided with sufficient lateral movement at the receiving bay level to rotate the cask between horizontal and vertical positions by means of continuous cask rotation with the transporter locked in place. For BWR designs with building size constraints, an acceptable alternative is to move the transporter to provide longitudinal travel and to use the building crane to provide vertical travel. For this alternative, precise alignment and control of the transporter are mandatory. The precision of the movement of the transporter will be consistent with that of the building crane. Movements of the crane and the transporter will be controlled at a station located at the elevation of the cask receiving bay.

- The cask handling crane will have a drive system that will permit continuously variable speed and will include a microdrive feature. A "fast" speed will also be included. Limit switches or other protective devices will be provided to limit the fast speed to times when the crane is unloaded.

6.1.2 Evaluation

On the basis of its review of the material provided on the overhead bridge crane in Chapter 7 of the Evolutionary Requirements Document, the staff found no nonconformances with the guidance of SRP Section 9.1.5, "Overhead Heavy Load Handling Systems." However, there is insufficient detail (e.g., with regard to the design layout, which shows the functional geometric layout of the handling equipment, including the areas of movement over and around the fixed locations of safety-related facilities during the handling of heavy loads, and with regard to the adequacy of operator training, load-handling procedures, and instructions) for the staff to determine if the various handling operations can be performed safely for specific designs. Therefore, the staff will require the designer or applicant to demonstrate that the design of the overhead bridge crane complies with the guidance in SRP Section 9.1.5.

6.2 Accident-Prevention Strategies

Sections 1.5.7 and 2.3.2.3.2 of Chapter 7 of the Evolutionary Requirements Document describe the requirements related to the loading and handling of spent fuel casks to prevent fuel handling accidents. EPRI discusses three methods of providing assurance that a spent fuel shipping cask will not drop into the fuel pool:

(1) Design the plant layout to physically preclude the possibility of a cask drop into the pool.

(2) Use the single-failure-proof philosophy when designing the crane (i.e., use a redundant load path crane and rigging).

(3) Use a small shuttle cask to transfer fuel assembles from the spent fuel pool to the shipping cask.

Section 1.5.7 of Chapter 7 notes that the third method requires further development to determine if it is a viable approach for refueling activities, but does not rule it out. It also states that the first method (the plant layout approach) is preferable over the other two methods and that "the single-failure-proof crane should only be used in plants that have building restrictions which prevent the plant design method." Section 2.3.2.3.2 of Chapter 7 implements this policy by specifying restrictions on crane travel. (Sections 2.3.1.1.4 and 2.3.1.2.4 of Chapter 7 require the pool structure and fuel storage racks to be designed to withstand other dropped loads.)

6.3 Sabotage Considerations

The staff also considered the possibility of a saboteur tampering with the crane to damage spent fuel rods and cause a release from the spent fuel pool. The plant layout method of protecting against the drop of a spent fuel shipping cask into the fuel pool, stated in the Evolutionary Requirements Document as being preferred, would significantly reduce this possibility and could contribute to meeting the provisions of the Commission's severe accident policy statement. The redundancy of the single-failure-proof-crane method is a less desirable way of protecting against deliberate sabotage. However, because 10 CFR 73.55 does not require licensees to design equipment to prevent tampering, either method is acceptable.

6.4 Radiological Considerations

The spent fuel cask servicing and decontamination areas will be close to the loading area to minimize the contamination path created when the wet cask is moved for decontamination. This arrangement is consistent with the guidelines of Regulatory Guide 8.8 for minimizing the spread of contamination and is acceptable.

6.5 Accident Analysis

In the DSER for Chapter 7, the staff noted that EPRI had not provided an accident analysis for the fuel cask drop accident covered in Chapter 7 of the Evolutionary Requirements Document. The staff concluded that the Evolutionary Requirements Document should address and specify the ALWR design requirements to mitigate the radiological consequences of the release of fission products from irradiated fuel in a spent fuel cask that is postulated to drop during cask handling operations. This was identified as an open issue in the DSER.

EPRI revised Table B.1-2 of Appendix B to Chapter 1 to require that ALWRs meet the requirements in Regulatory Guides 1.13, "Spent Fuel Storage Facility Design Basis," and 1.25, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors." Regulatory Guide 1.13 requires the plant to be designed taking into consideration fuel handling accidents, and Regulatory Guide 1.25 provides assumptions and parameters that should be used when evaluating radiological consequences of a fuel handling accident. This is in accordance with the guidance in SRP Section 15.7.4 and is acceptable. Therefore, this DSER open issue is closed. Because EPRI further stated that specific details of how the plant design will satisfy the regulatory guide requirements were beyond the level of detail typically provided in the Evolutionary Requirements Document, the staff will review these details during its review of an application for FDA/DC.

7 OTHER RELATED SYSTEMS AND EQUIPMENT

7.1 Fuel Handling System

7.1.1 Key Design Requirements

Section 2.3.4.1 of Chapter 7 of the Evolutionary Requirements Document specifies that designs for the fuel handling system and equipment will conform to ANSI/ANS 57.1, "Design Requirements for Light Water Reactor Fuel Handling Systems." The Evolutionary Requirements Document lists key requirements, including the following:

- Grapples and mechanical latches that will carry fuel assemblies or control element assemblies will be designed so that accidental opening will be mechanically prevented. Actuation of the grapple will not depend on gravity or the orientation of the fuel assembly.

- The design of the refueling machine and grapple will prevent the possibility of dropping a fuel assembly as a result of a single active failure in the machine mechanisms.

- The design of the fuel assembly grapple will be such that the grapple cannot actuate and raise the fuel assembly unless the grapple is fully engaged.

- Guides will be provided within the refueling machine mast to provide lateral restraint to components being transported horizontally and during the insertion or withdrawal of the components.

- The refueling machine hoist will be provided with a load-measuring device with a visual display of the hoist load. Interlocks will be provided to interrupt hoisting if the hoist load increases beyond or decreases below the safe limit. The load limit that interrupts hoisting will be adjustable within certain overall setpoint limits recommended by the fuel designer.

- The mast must be able to rotate to ensure that each fuel assembly is correctly placed in the appropriate location.

- If the primary system for determining the position of the mast fails or becomes inoperable, a secondary system must be available to ensure the mast does not damage fuel assemblies.

- All fuel handling tools and equipment will be designed so that in the event of an unexpected failure, the fuel assembly will remain in a safe condition and in a location with adequate cooling and shielding.

- Conduits at least 6 inches in diameter will be provided under the rails of the refueling machine. The conduits will be spaced at approximately 20-foot intervals to allow temporary electrical cables and hoses to pass under the rails without obstructing the motion of the refueling machine.

- The drive systems for all fuel handling equipment (refueling machine, cranes, etc.) will deenergize and stop when the component actuation switch is released so that equipment is in motion only when the operator is actuating the equipment. This feature reduces the possibility of a fuel assembly being damaged as a result of inadvertent equipment operation.

- The capability for local emergency shutdown of the power supply to the fuel handling equipment will be included in the equipment design and will be independent of and physically separated from the normal equipment controls. The emergency shutdown controls will be located in the fuel handling work areas.

- The refueling machine bridge, trolley, and hoist motion will be driven by variable-speed electric motors. Interlocks will be provided to limit the hoist speed and load when the hoist is in the vicinity of the reactor core and to prohibit motion outside prescribed boundaries.

- Coordinate location of the bridge, trolley, and hoist will be indicated on the refueling machine control console by digital readout devices. The position indication will be accurate within a tolerance of 1/8 inch. A backup system of position indication also will be provided.

- Interlocks will be provided to limit the motion of the refueling machine hoist, bridge, or trolley to one rectilinear direction at any time. Automatic motion of the bridge or trolley will be prevented when the mast is not fully retracted. Manual operation of the bridge and trolley resulting in motion of up to 1/8 inch will be possible when the mast is not fully retracted.

- All actuations of interlocks on the refueling machine and fuel transfer system (PWR) will be displayed on a panel that indicates an activated interlock, the action required to eliminate the interlock condition, and possible reasons why the interlock was activated. The interlocks will be designed to minimize the potential for fuel assembly damage.

- In the event of loss of required power and/or air pressure, the fuel handling system will be capable of manual operation to ensure the equipment is in a safe condition.

- The refueling machine will be designed so that in the event of loss of control or power, the fuel assembly or control component being handled will remain in the current position. In addition, upon restoration of power, the refueling machine will not operate until it is actuated by the operator.

7.1.2 Evaluation

On the basis of its review of the material provided on the fuel handling system in Chapter 7 of the Evolutionary Requirements Document, the staff found no nonconformances with the criteria of SRP Section 9.1.4, "Light Load Handling System." However, there are insufficient details (e.g., with regard to the design layout, which shows the functional geometric layout of the handling equipment and defines the travel paths through, over, and around rigid objects during fuel handling) for the staff to determine if various handling operations can be performed safely for specific designs. Therefore, the staff will require the designer or applicant to demonstrate that the design of the fuel handling system complies with the guidance in SRP Section 9.1.4.

To minimize the dose to divers who will maintain permanently installed underwater fuel handling equipment, Section 2.3.4.5 of Chapter 7 of the Evolutionary Requirements Document specifies that all such equipment will be located so that the radiation levels at the equipment location from fuel assemblies stored in the spent fuel pool are minimized. The Evolutionary Requirements Document further requires that all underwater fuel handling equipment be removable and/or replaceable without having to lower the water levels in the refueling pool or in the spent fuel pool. In addition, this equipment will be designed to permit easy decontamination. Section 2.3.4.9.3 of Chapter 7 specifies that the refueling machine will be provided with a positive mechanical stop to prevent a fuel assembly from being lifted above the minimum safe shielding water depth. The above features of the fuel handling system are intended to maintain occupational radiation exposure levels to refueling personnel as low as is reasonably achievable (ALARA). The staff concludes that these features are acceptable.

In Section 7.1.2 of the DSER, the staff restated its position that either the BWR refueling platform assembly should be classified as seismic Category I or EPRI should make a commitment to design this item to withstand the loads resulting from the safe shutdown earthquake (SSE) without any damage to fuel or safety-related equipment. This was identified as an open issue in the DSER. In response to the DSER, EPRI revised Section 2.3.4.1.1 of Chapter 7 to require that the BWR refueling platform assembly be classified as seismic Category II. As discussed in Section 4.3.2 of Chapter 1 in this report, Section 4.3.2 in Chapter 1 of the Evolutionary Requirements Document now contains a requirement that Positions C.2 and C.4 of Regulatory Guide 1.29, "Seismic Design Classification," be applied to seismic Category II items. A commitment to these positions provides reasonable assurance that the BWR refueling platform assembly will be designed and constructed to withstand the loads resulting from the SSE without any damage to fuel or safety-related equipment and is, therefore, acceptable. The staff concludes that this DSER open issue is closed.

7.2 Fuel Transfer System (PWR)

Section 4.3.4.4 of Chapter 7 of the Evolutionary Requirements Document states that a hinged, quick-opening tube closure will be provided for the transfer tube opening inside the reactor containment building in a PWR design. EPRI states that this feature will facilitate flange removal and installation and will result in lower occupational exposure to workers performing these operations. To lower the dose to personnel operating the fuel transfer equipment, the radiation shielding for the fuel transfer system will be designed to limit, to the extent possible, gaps between liner plates, biological shields, and floors. The staff concludes that these design features are intended to reduce radiation exposure to workers during refueling operations and are, therefore, acceptable.

During the transfer of irradiated spent fuel as part of refueling operations, transient or temporary very high radiation levels (e.g., in areas adjacent to the spent fuel transfer tube in PWRs and upper drywell areas in BWRs) could exist that could result in potentially lethal doses to personnel. Examples of other plant areas where the potential for transient very high radiation levels may exist are the reactor cavity areas below the reactor pressure vessel and the seal table room. The sources of very high radiation in both of these areas are the incore thimbles (for PWRs) and incore detectors and associated drive cables. These can become activated while inserted in the reactor core and cause transient high radiation levels in these areas when withdrawn from the core.

In the DSER for Chapter 7, the staff stated that EPRI and/or the plant designer should identify all accessible areas where, during normal and anticipated operational occurrences, personnel could receive a radiation dose of 100 rad or more in 1 hour. In addition, EPRI should describe design considerations that will ensure that personnel were not exposed to potentially lethal doses of radiation. These design considerations should provide more positive access controls than are provided by locking area access doors (as is required by 10 CFR 20.203). This was identified as an open issue in the DSER.

In response to the DSER open issue, EPRI revised Section 4.2.9 of Chapter 6 to require that plant designers identify areas where, during normal operation and anticipated operational occurrences (not related to reactor accident/degraded core conditions), personnel could receive a radiation dose of 100 rad or more in 1 hour. Where practicable, the plant will be designed to preclude accessibility to these areas. For those areas that must be accessible on an occasional basis for maintenance and inspection, the plant designer will ensure that accessibility is limited through the use of positive access controls. The staff concludes that these measures will serve to reduce the possibility of personnel overexposures and are acceptable. Therefore, this DSER open issue is closed.

7.3 Fuel Handling Area Heating and Ventilation System

The staff's evaluation of the fuel handling area heating and ventilation system is provided in Chapter 9 of this report.

7.4 Irradiated Fuel Inspection and Repair Equipment

Section 2.3.5 of Chapter 7 of the Evolutionary Requirements Document specifies that a dedicated space will be provided in the spent fuel pool area for the inspection, repair, and reconstitution of fuel assemblies. This space will be large enough to accommodate fuel consolidation equipment. This will facilitate fuel inspection and repair activities.

In the DSER for Chapter 7, the staff concluded that the Evolutionary Requirements Document should describe design features and/or operational practices used during fuel reconstitution to segregate the dedicated portion of the fuel pool from the rest of the pool and confine the potential release of any irradiated fuel particles in order to prevent the spread of irradiated fuel particles to other parts of the fuel pool. This was identified as an open issue in the DSER.

EPRI revised Section 2.3.5.1 to state that it is envisioned that equipment used in the ALWR for contamination control be state-of-the-art at that time. In addition, fuel pool segregation requirements will be dependent on the equipment design. Because specific equipment design is beyond the scope of the Evolutionary Requirements Document, the staff concludes that EPRI's response is acceptable. Therefore, the DSER open issue is closed.

7.5 Reactor Disassembly and Servicing Equipment

Section 2.3.6.3 of Chapter 7 of the Evolutionary Requirements Document states that the plant designer will provide a stud tensioner design that will minimize the number of operations needed to move the reactor vessel stud tensioners and to remove the nuts and washers. Since these operations will be performed in a high-radiation area, the use of this device will result in lower occupational exposures to plant personnel performing these tasks. Section 2.3.6.4 of Chapter 7 specifies that the reactor building will be arranged to permit the underwater storage of all removable reactor internals with resultant radiation levels maintained at less than 2-1/2 mrem/hour. These features are intended to maintain doses to personnel ALARA during disassembly and servicing of the reactor. The staff concludes that these features are acceptable.

Section 3.3.2 of Chapter 7 specifies the following features for BWR designs to facilitate reactor disassembly:

- special lift rig to lift and move shield blocks
- drywell head design to facilitate the removal and installation of the head
- special handling equipment to remove, transport, and store reactor pressure vessel studs

By facilitating reactor disassembly, EPRI concludes that these features will shorten the refueling outage time and thereby result in lower occupational exposures. The staff concludes that this approach to design is acceptable. However, because there is insufficient detail for the staff to determine if the specific design features are acceptable, the staff will evaluate these features during its review of an application for FDA/DC.

8 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 7 of the Evolutionary Requirements Document for the design of fueling and refueling systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the design of the fueling and refueling systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the Standard Review Plan (SRP) (NUREG-0800), or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 7 of the Evolutionary Requirements Document specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose fueling and refueling systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 7 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
GENERIC SAFETY AND LICENSING ISSUES

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address the resolution of generic safety issues (GSIs) in Appendix B of each chapter. In the DSER for Chapter 7 of the Evolutionary Requirements Document, the staff evaluated EPRI's requirements to address the resolution of GSI 82, "Beyond Design Basis Accidents in Spent Fuel Pools." It identified EPRI's requirements to address GSI 82 as an open issue because EPRI's proposed use of high-density storage racks increases the probability of a Zircaloy fire compared to a design using low-density storage racks. The staff recommended that, as a minimum, EPRI commit to use low-density storage racks, at least for the most recently discharged fuel.

In Revision 1 of the Evolutionary Requirements Document, submitted by letter dated September 7, 1990, EPRI relocated its requirements to address GSIs that were unresolved as of January 1, 1990, to Appendix B to Chapter 1. As a result, a number of GSIs that were addressed in the original Evolutionary Requirements Document are no longer addressed. The staff has provided its evaluation of EPRI's requirements to address GSIs in Appendix B to Chapter 1 of this report and has also documented its closure of open and confirmatory issues associated with GSIs no longer addressed by EPRI. Therefore, the DSER open issue associated with GSI 82 is closed.

The Appendix B now in Chapter 7 contains figures showing the general refueling arrangement for a BWR and a PWR.

CHAPTER 8, "PLANT COOLING WATER SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 8, "Plant Cooling Water Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 8 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering Nuclear Power; Bechtel Power Corporation; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Sargent and Lundy Engineers; Stone and Webster Engineering Corporation; Westinghouse Electric Corporation; and EPRI.

On December 30, 1988, EPRI submitted the original version of Chapter 8 of the Evolutionary Requirements Document for staff review. By letters dated March 22 and September 14, 1989, the NRC staff requested that EPRI supply additional information. EPRI provided the information in its responses dated August 18, September 15, and December 22, 1989, and January 18, 1990. Topic papers in Appendix B of the original version of this chapter were relocated to Appendix B of Chapter 1.

On January 15, 1991, the staff issued its DSER for Chapter 8 of the Evolutionary Requirements Document. On April 10, 1991, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 8, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 8, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 8 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 8

Chapter 8 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the plant cooling water systems.

The key topics addressed in the Chapter 8 review include EPRI-proposed design requirements for the following systems:

- component cooling water
- service water
- circulating water
- ultimate heat sink and normal power heat sink

* chilled water
* fuel pool cooling and cleanup

1.3 Policy Issues

During its review of Chapter 8 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 8 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) human factors considerations (2)

(2) probable maximum precipitation (3.2)

(3) justification for the reduction of surveillance testing and improved limiting conditions for operation (3.2)

(4) biofouling in service water systems (3.2, 5.2, and Appendix B to Chapter 1)

(5) inservice testing of pumps and valves (3.3)

(6) heat exchanger testing (3.3 and Appendix B to Chapter 1)

(7) division requirements for the component cooling water system of the nuclear steam supply system for BWRs (4.2)

(8) design of the reactor coolant pump seal cooling system (5.2)

(9) evaluation of postulated electric power supply failure or essential service water system (5.2)

(10) evaluation of postulated intake structure failure (5.2)

(11) reliability of essential service water system (5.2 and Appendix B to Chapter 1)

(12) independence of decay heat removal cooling from fuel pool cooling and cleanup system (9)

Confirmatory Issues

(1) effect of inadvertent actuation of non-safety-related equipment on safety-related components (2)

(2) sabotage protection (3.3)

(3) flow indication for the component cooling water system (4.2)

(4) compliance with "Federal Guidelines on Dam Safety" (7.3)

(5) maximum temperature for essential service water system (7.3)

The final disposition of each of these issues is discussed in greater detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All issues identified in the DSER for Chapter 8 of the Evolutionary Requirements Document have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.8.V-1 pump minimum flow line or recirculation line design (3.2)

E.8.V-2 reduction of surveillance testing (3.2)

E.8.V-3 availability of emergency power supply for the fuel pool cooling and cleanup system following a design-basis accident (9)

2 SCOPE AND KEY FUNCTIONAL REQUIREMENTS

Section 1 of Chapter 8 of the Evolutionary Requirements Document contains those policies established by the ALWR Utility Steering Committee relating to the design approach and process, potential alternatives, water quality, and configuration as they relate to the plant cooling water systems of ALWR plant designs. The principal functions of the plant cooling water systems will be to remove heat from plant systems, structures, and components during normal operation, shutdown, and accident conditions, including the removal of decay heat from the reactor, and also to act as a pressure boundary, when applicably to prevent the release of radioactivity to the environment. Chapter 8 specifies the requirements proposed by EPRI for the component cooling water, service water, circulating water, chilled water, and fuel pool cooling and cleanup systems, and the ultimate and normal power heat sinks.

Section 1.5.1 of Chapter 8 states that the goals considered in the development of the EPRI requirements for the plant cooling water systems include the simplification and consolidation of system designs; support of other plant equipment to meet safety and availability goals; minimization of the possible effects of mud, silt, organisms, and the harsh chemistry of heat sink water on the plant cooling water systems; and the use of operating pressures to reduce the contamination of closed, treated cooling water systems by raw water.

Section 1.5.2 of Chapter 8 specifies requirements to improve the performance of the plant cooling water systems in the areas of thermal and hydraulic analyses of piping and heat transfer systems; analytical models of the anticipated performance of the heat sinks during design-basis conditions; optimization of flows, heat transfer areas, and load assignments; degradation of system components due to corrosion, silting, and bifouling; and erosion and corrosion considerations.

Section 1.5.3 of Chapter 8 states that in cases where the evaluation and selection of alternatives in the design will be left to the designer, it is the intent of the Evolutionary Requirements Document to establish a reference design that would minimize the effect on the standard design.

Section 1.5.4 of Chapter 8 specifies requirements to reduce the corrosive effects of harsh chemistry, silt, and biological fouling on the plant cooling water systems. EPRI specifies that direct service water will not be used for component cooling; raw service water will be treated to reduce the effect of mud, silt, or organisms; materials that offer greater resistance to water chemistry conditions should be used; and provisions to facilitate the inspection of service water piping should be made.

Section 1.5.5 of Chapter 8 specifies that in plant designs referencing the Evolutionary Requirements Document, a combined plant cooling water system should be used; that is, one that allows the assignment of some non-safety-grade loads to a component cooling water system that will also handle safety loads.

Non-Safety-Related Components

Section 2.3.12 of Chapter 8 of the original Evolutionary Requirements Document states that failure of non-safety-related components before, during, or after design-basis events must not jeopardize the operation of safety-related components. In the DSER for Chapter 8, the staff stated that EPRI had committed to expand the definition of failure to include consideration of the effect of inadvertent actuation of non-safety-related equipment on safety-related components. This was identified as a confirmatory issue.

This requirement has been renumbered and now appears as Section 2.3.9 of Chapter 8. To address this issue, EPRI added the single-failure criterion to Section 2.3.2.5 of Chapter 1 to comply with the requirements of Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Section 2.3.2.5 of Chapter 1 of the Evolutionary Requirements Document requires, among other things, that the plant designer identify potential single equipment failures that could occur coincident with the initiating events identified in Section 2.3.2 of Chapter 1. EPRI states that the intent of this requirement is to identify single failures important to fuel and reactor pressure boundary limits in a manner consistent with historical analysis. Since the effects of single failures on plant response to each of the anticipated operational occurrences and accidents will be addressed in the safety analysis for plant-specific designs, the staff concludes that the added requirements are acceptable. Therefore, this DSER confirmatory issue is closed.

Human Factors Considerations

In the DSER for Chapter 8, the staff identified an open issue regarding EPRI's approach to incorporating human factors considerations into the Evolutionary Requirements Document. The staff has provided its human factors assessment of the Evolutionary Requirements Document in Appendix D to Chapter 10 of this report. Therefore, this DSER open issue is closed.

3 COMMON REQUIREMENTS

3.1 Introduction

Since PWR and BWR plants have many similarities in their safety-related and non-safety-related cooling water systems, Sections 2 and 3 of Chapter 8 of the Evolutionary Requirements Document define the common requirements for the design of plant cooling water systems applicable to both PWR and BWR plants. Additional requirements that are specific to individual cooling water systems of the group are addressed separately in Sections 4 through 9 of this chapter.

3.2 System Requirements

Key requirements for plant cooling water systems include the following:

- Raw service water will not be used directly for equipment or component cooling. Equipment and component cooling water will be supplied from a closed-loop component cooling water system, which will serve as an intermediate system between equipment or components and the service water system. This requirement will limit the problem of dealing with the fouling and corrosion caused by raw service water to one system rather than throughout the plant.

- Each division of a safety-related system will be provided with an independent onsite emergency power source.

- Cross-connections between the safety-related divisions of the system will not be allowed unless the designer demonstrates a compelling safety, operability, or availability need; a reliable administrative control will be implemented to ensure that cross-connections are not mispositioned; and the single-failure criterion is met for passive failure. In addition, cross-connections, if used, will only be allowed to be open during plant shutdown (such as for system maintenance).

- The nominal flow velocities in the piping of the plant cooling water systems will not exceed 12 ft/sec nor be less than 8 ft/sec for normal operating conditions.

- Pumps will provide at least a 7-percent margin in head at the pump design point. The head-versus-flow curve will rise continuously from the design point to shutoff.

- The available net positive suction head (NPSH) will be at least 25 percent, but not exceed 10 feet of water, greater than the required NPSH specified by the pump vendor.

- The use of installed, dedicated pump recirculation lines will be avoided. The plant cooling water system will be designed so that the pumps do not operate below the minimum flow required for pump protection for all operating modes. However, if flow is inadvertently blocked, the plant designer will ensure that sufficient time is available for the operator to stop the pump without excessive pump damage. Because a plant designer will have flexibility in system design, the staff will review the detailed system design and operation during its review of an individual application for FDA/DC to determine the need for pump minimum flow lines or recirculation lines to allow the development of full-flow conditions for periodic testing.

- Adequate filtration and/or silt-removal capability will be provided for raw water systems (i.e., the service water system and the circulating water system). Provisions to facilitate periodic cleaning and back-flushing, as necessary, will be included.

- Raw water systems will have provisions for the injection of biocides to limit microbial growth.

- Means will be provided to detect and identify leaks into the system from systems that contain radioactivity.

- Status indication will be provided for any switched function. Any bypassed or manual override status will be indicated.

- Instrumentation will be provided to monitor process conditions and will be sufficient to analyze the performance of the system.

Probable Maximum Precipitation

In Section 3.1 of the DSER for Chapter 8, the staff identified an open issue concerning the value for probable maximum precipitation to be used in the envelope of plant site design parameters specified in Chapter 1. The staff's evaluation of this issue is provided in Section 4.5.2 of Chapter 1 and Section 3.3.1 of Chapter 6 of this report. Therefore, this DSER open issue is closed.

Surveillance Testing

Section 2.3.9 of Chapter 8 of the original Evolutionary Requirements Document stated that plant cooling water systems will be designed to reduce the required surveillance testing and to improve limiting conditions for operation as compared to those at current plants. In the DSER for Chapter 8, the staff stated that a reduction from current criteria for surveillance testing should require demonstratively improved diagnostic techniques or service data. This was identified as an open issue. In response to this open issue, EPRI provided additional requirements in Section 2.3.6 to require that the system be designed to reduce the required effort for surveillance testing and improve limiting conditions for operation (LCOs), as compared to current plants. The plant designer is required to justify recommended reductions in surveillance testing. EPRI states that reduction in surveillance testing will increase plant availability and improved LCOs will increase plant availability through the Increased equipment margin or increased redundancy of components and more reliable equipment. Effort required for surveillance testing can be reduced by using improved diagnostic techniques. The staff concludes that reductions in surveillance testing will be considered on a plant-specific basis and it will review individual applications for FDA/DC to determine the extent of any such reductions. The staff concludes that the added requirements and rationale are acceptable. Therefore, this DSER open issue is closed.

Biofouling

In the DSER for Chapter 8, the staff identified an open issue related to biofouling and recommended that EPRI contact utilities and other sources mentioned in Information Notice 89-16, "Biofouling Agent: Zebra Mussel," so that the experiences and lessons learned concerning zebra mussel fouling could be factored into the Evolutionary Requirements Document. In response to this open issue, EPRI revised Section 3.7.2.1 of Chapter 8 to address Generic Issue 51, "Improving the Reliability of Open-Cycle Service Water Systems," (as described in Enclosure 1, "Improving the Reliability of Open Cycle Service Water Systems," of Generic Letter (GL) 89-13). Section 3.7.2.1 requires, in part, that raw water systems have provisions for biocide injections where discharge is allowed and the type of biocide, the concentration of injection, and the frequency of injection be determined by the plant designer on the basis of environmental regulations, makeup water chemistry, operating conditions, including wet layup, and materials. In addition, EPRI revised Section 5.4.3.3 of Chapter 8 to require, in part, that the plant designer include provisions to ensure that surveillance of biofouling and silting can take place. EPRI has stated that Davis-Besse plant personnel have been contacted and information in EPRI's Service Water Assistance Program (SWAP) has been reviewed to address concerns about the zebra mussel. The staff concludes that EPRI has made reasonable efforts to comply with the guidelines in GL 89-13. Therefore, the requirements for controlling biofouling to address Generic Issue 51 are acceptable and this DSER open issue is closed.

3.3 Equipment Requirements

Inservice Testing of Pumps and Valves

In SECY-90-016, the staff concluded that the requirements of Section XI of the American Society of Mechanical Engineers Boiler and Pressure Code (ASME) Code provide information on the operational readiness of the components but, in general, do not necessarily provide information for verifying the capability of the components to perform their intended safety functions. The staff concluded that the ASME Code does not ensure the level of component operability that is desired for the evolutionary LWR designs.

Accordingly, in SECY-90-016, as supplemented by the staff's April 27, 1990, response to comments by the Advisory Committee on Reactor Safeguards (ACRS), the staff recommended criteria to the Commission to be used to supplement Section XI of the ASME Code. In its staff requirements memorandum (SRM) of June 26, 1990, on SECY-90-016, the Commission approved the staff's position for evolutionary LWRs.

The SRM stated that the following provisions should apply to all safety-related pumps and valves and not be limited to ASME Code Class 1, 2, and 3 components:

- Piping design should incorporate provisions for full-flow testing (maximum design flow) of pumps and check valves.

- Designs should incorporate provisions for testing motor-operated valves under design-basis differential pressure.

- Check valve testing should incorporate the use of advanced nonintrusive techniques to address degradation and performance characteristics.

- A program should be established to determine the frequency necessary for the disassembly and inspection of pumps and valves to detect unacceptable degradation that cannot be detected through the use of advanced nonintrusive techniques.

These items on testing motor-operated valves should be considered applicable to all safety-related power-operated valves. In addition, the staff agreed with the recommendation of the ACRS that the guidelines of GL 89-10, "Safety-Related Motor-Operated Valve Testing and Surveillance," be applied to evolutionary LWR designs. The ACRS also recommended that the staff resolve the check-valve testing and surveillance issue and that consideration be given to industry-proposed alternative ways of meeting inservice testing (IST) and surveillance requirements.

Section 3.2 of the DSER for Chapter 8 contained an extensive discussion of staff concerns related to IST of pumps and valves. The staff was concerned about a requirement in Chapter 8, Section 3.2.7, Revision 1, which stated that IST of essential pumps and valves will be performed in accordance with American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) OM-6 and OM-10. In the DSER, the staff identified this as an open issue. In a letter dated May 22, 1991, EPRI responded to the DSER by stating that Section 12 of Chapter 1 of the Evolutionary Requirements Document provides general requirements for pumps and valves. EPRI further stated that to ensure that the testing requirements for pumps and valves in Chapter 8 are consistent with the Chapter 1 requirements, it would revise Section 3.2.7 of Chapter 8 to require that system design include provisions for IST of safety-related pumps and valves in accordance with the requirements in Chapter 1, Sections 12.2.7 and 12.4.3. EPRI revised Section 3.2.7 of Chapter 8 by inserting this requirement and deleting references to OM-6 and OM-10. As a result, the staff's evaluation of the IST requirements for all ALWR safety-related pumps and valves is now in Section 12.2 of Chapter 1 of this report. Therefore, this DSER open issue is closed.

<u>Valves</u>

Section 3.3.3.3 of the original Evolutionary Requirements Document of Chapter 8 required local manual operation of valves unless remote motor operators are required for safety functions or if local manual operation is impracticable. Motor operators have been identified as a common cause of valve failures.

In letters dated April 28 and September 14, 1989, the staff commented that it would be desirable for certain valves to include remote position indication, even if the valves had no motor operators. In its March 16, 1990, reply, EPRI referenced requirements in Chapter 10 of the Evolutionary Requirements Document. The staff's evaluation of EPRI's requirements for position indication of manual valves is provided in Chapter 10 of this report.

Heat Exchangers

Section 3.5.1 of Chapter 8 states that performance of key heat exchangers will be tested when heat load becomes available and a test plan or schedule is developed by the plant designer. Many operating plants do not have the capability to test the heat load of the heat exchangers. It has been determined that adding this heat load testing capability after the plant is already in operation might not be economically feasible. In the DSER for Chapter 8, the staff concluded that vendors should consider including the capability for performance testing of key heat exchangers during the planning and design stage of the ALWR plants. Enclosure 2 ("Program for Testing Heat Transfer Capability") of GL 89-13 should be consulted and incorporated in the Evolutionary Requirements Document as appropriate. This was identified as an open issue in the DSER.

In response to this concern, EPRI revised Chapter 8 to ensure adequate instrumentation is available for performance testing of heat exchangers in order to meet the recommendations of GL 89-13. Section 3.8.2 of Chapter 8 identifies requirements necessary to ensure temporary flow instrumentation can be installed for heat exchanger testing. Section 3.8.5 of Chapter 8 requires that pressure and temperature instrumentation be provided for safety-related heat exchangers. Section 3.8.6 of Chapter 8 requires that the accuracy of the temperature, pressure, and flow instruments be sufficient to calculate the overall heat transfer coefficient within limits required to verify heat transfer capability. The staff concludes that these design requirements meet the recommendations of Enclosure 2 to GL 89-13 and are acceptable. Therefore, the DSER open issue is closed.

Trash Racks and Traveling Screens

Section 3.3.5.1 of Chapter 8 requires that trash racks be provided upstream of pumps susceptible to damage from large debris, establishes 1 inch as the minimum spacing between bars, and requires provisions to manually clear debris.

In the DSER for Chapter 8, the staff stated that EPRI had committed to provide a requirement that provisions to manually clear debris from trash racks be coordinated with the design of security barriers and intrusion detection systems so that provisions for physical access do not provide a potential path for covert penetration from the water into the plant's protected area. In the DSER, the staff identified this as a confirmatory issue. The staff has verified that EPRI has revised Section 3.3.5.8 of Chapter 8 to reflect this commitment. Therefore, this DSER confirmatory issue is closed.

3.4 Conclusion

The staff concludes that Section 3 of Chapter 8 of the Evolutionary Requirements Document for the design of plant cooling water systems does not conflict with the guidance in SRP Sections 9.2.1, "Station Service Water System," and 9.2.2, "Reactor Auxiliary Cooling Water Systems," and is, therefore, acceptable.

4 COMPONENT COOLING WATER SYSTEMS

4.1 Scope and Function

The component cooling water systems (CCWSs) will be closed loop systems that will provide the following:

- a method to remove decay heat and waste heat from the reactor, plant systems, structures, and components and transfer the heat to the service water system
- protection against leakage of service water into the primary containment and reactor systems
- protection against release of radiological contamination into the ultimate heat sink

The systems will be divided into component cooling water-nuclear steam supply system and turbine building component cooling water system.

4.2 Component Cooling Water System-Nuclear Steam Supply System

The component cooling water system of the nuclear steam supply system (CCWS-NSSS) will supply cooling water to safety-related and non-safety-related plant components during normal operation and to safety-related components during postulated accident and emergency conditions. The CCWS-NSSS will consist of two (for PWR) or three (for BWR) totally independent divisions, each of which will have two pumps, two heat exchangers, one surge tank, one chemical addition tank, and associated piping, valves, instrumentation, and controls. In Section 4.2 of Chapter 8 of the Evolutionary Requirements Document, EPRI establishes requirements for the design of the CCWS-NSSS. The key requirements include the following:

- During normal operation, one pump and one heat exchanger per division will be in operation to provide the required system flows and heat transfers.
- During normal shutdown, all divisions with two pumps and two heat exchangers will be in operation.
- For safe cold shutdown, two pumps and two heat exchangers in either one of two divisions (PWR) or two pumps and two heat exchangers in each of two divisions (BWR) will be capable of removing the heat loads.
- For BWR decay heat removal during shutdown, three divisions will be in operation for cooling the reactor system.
- Flow of system cooling water to non-safety-related miscellaneous heat loads will be automatically isolated on the receipt of an engineered safety systems actuation signal. Isolation will also be provided on indication of gross leakage between safety-related and non-safety-related systems.

- Makeup water will be provided from a safety-grade source.

In the DSER for Chapter 8, the staff noted that the requirements for the BWR CCWS-NSSS appeared to be inconsistent with the requirements established in Chapter 5 of the Evolutionary Requirements Document for BWR core coolant inventory control (CCIC) and decay heat removal (DHR) and identified this inconsistency as an open issue.

In response to this concern, EPRI stated that two out of three divisions are required for plant cooldown within 36 hours with a concurrent single failure, but on a realistic basis, only a single division is required to provide CCIC and DHR cooling for transients and loss-of-coolant accidents (LOCAs). EPRI revised Section 4.2.1.9.1 of Chapter 8 to be consistent with Section 4.5.2.4.4 of Chapter 5. These two sections require that the DHR system, with two divisions in operation, permit cooling the reactor from saturation conditions at 135 psig to <212 °F within 36 hours after rods are inserted (viz., plant emergency shutdown). In addition, Section 4.2.1 of Chapter 5 requires that each of these divisions be capable of providing CCIC and DHR on a realistic basis. No specific requirements for rate and extent of cooldown are imposed.

The staff concludes that there is no longer a discrepancy between the two chapters regarding the number of BWR divisions required during a LOCA and, therefore, the DSER open issue is closed.

In the DSER for Chapter 8, the staff concluded that Section 4.4.4.4 of Chapter 8 did not provide instrumentation for flow indication for the CCWS and stated that EPRI had committed to add a requirement for flow indication. The staff has verified that the requirement for permanent flow instrumentation has been added to Section 3.8.4 of Chapter 8. Therefore, this DSER confirmatory issue is closed.

The staff concludes that the design requirements for the CCWS-NSSS in Section 4.2 of Chapter 8 do not conflict with the guidance in SRP Sections 9.2.1 and 9.2.2 and General Design Criterion 44 of Appendix A to 10 CFR Part 50 and are, therefore, acceptable.

4.3 Turbine Building Component Cooling Water System

The turbine building component cooling water system (TBCCWS) will be a non-safety-related system that will supply cooling water to various non-safety-related auxiliary components in the turbine building. Section 4.3 of Chapter 8 of the Evolutionary Requirements Document defines performance requirements and system arrangement for the TBCCWS. Specifically, the TBCCWS will be a closed-loop system containing two 100-percent pumps, two 100-percent heat exchangers, and the necessary cross-connecting headers, valves, instruments, and controls to recirculate 100 percent of the required cooling water flow to the individual non-safety-related cooling loads.

The staff concludes that the design requirements in Section 4.3 of Chapter 8 for the TBCCWS do not conflict with the guidance of SRP Section 10.4.5, "Circulating Water System," and are, therefore, acceptable.

5 SERVICE WATER SYSTEMS

5.1 Definition and Scope

The service water systems (SWSs) will consist of the essential service water system* and the nonessential service water system*.

5.2 Essential Service Water System

The essential service water system (ESWS) will be a safety-related open-loop system designed to provide cooling water to the tube side of the Component Cooling Water System-Nuclear Steam Supply System (CCWS-NSSS) heat exchangers and to transfer heat from these heat exchangers to the plant ultimate heat sink during normal operation and emergency conditions. The system will consist of two (for the PWR) or three (for the BWR) totally independent divisions, each of which will consist of two ESWS pumps, two heat exchangers, two strainers, and associated piping, instrumentation, and controls.

In Section 5.2 of Chapter 8 of the Evolutionary Requirements Document, EPRI establishes the requirements for the design of the ESWS. The key requirements include the following:

- The pumps will be vertical units located at the ultimate heat sink, with submerged pump suctions, to ensure that adequate net positive suction head will be available during all operating modes.
- Means will be provided to detect leakage into the ESWS from the CCWS. A system will be established to take and analyze water samples from the cooling pond (ultimate heat sink or cooling tower) periodically or when low water level occurs frequently in the CCWS surge tank during normal plant operation. A radiation monitor with a high-level alarm will be placed on the cooling pond blowdown.
- Service water pump discharge piping will be equipped with a strainer or a silt-removal capability or both. Provisions for periodic cleaning and backflushing, as necessary for the system surfaces, will be included.
- All system heat exchangers will be equipped with pressure and temperature instrumentation at the SWS inlets and outlets to record performance.

Generic Issue 23

In the DSER for Chapter 8, the staff concluded that the design requirements for the ESWS in Section 5 of Chapter 8 did not address reactor coolant pump (RCP) seal reliability for the ALWR. The staff concluded that, specifically for a PWR, EPRI should evaluate the possibility of providing an RCP seal

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*Referred to by EPRI as "safety service water system" and "non-safety service water system," respectively.

cooling system that is independent of the service water system to address the issue of RCP seal failure (Generic Issue (GI) 23, "Reactor Coolant Seal Failures"). In the DSER, the staff identified this as an open issue.

In response to this DSER open issue, EPRI stated that Chapter 3 had been revised to ensure seal leakage will be minimal following loss of seal cooling. Specifically, Section 3.4.2.3.4 of Chapter 3 now requires that the degradation of the shaft seal system be negligible following loss of both seal injection and pump cooling water for up to 1 hour. In addition, Section 3.4.2 3.5 of Chapter 3 now specifies that in the event of the loss of all ac power, reactor coolant system (RCS) leakage through the RCP shaft seals will be limited so that the reactor core will remain covered and natural circulation cooling of the core will be maintained for at least 8 hours. EPRI stated that an additional cooling water system was not specified because it would complicate the design and could possibly result in an additional service water system. The staff concludes that EPRI has provided information to address the intent of GI 23.

The staff's evaluation of EPRI's requirements to address GI 23 is given in Section 3.2.20 of Appendix B to Chapter 1 of this report. Therefore, this DSER open issue is closed.

Effects of Electric Power Supply Failure

In the DSER for Chapter 8, the staff recommended that EPRI evaluate the effects of electric power supply failure on the essential service water system and identified this as an open issue. To address this open issue, EPRI revised Chapter 11 of the Evolutionary Requirements Document to provide electric system design and station blackout requirements for the plant cooling water systems. Section 1.4 of Chapter 8 requires that safety-related plant cooling water systems be powered by Class 1E power supplies. Additionally, EPRI modified Section 2.3.2.2 of Chapter 1 to require that analysis and acceptance criteria for events involving multiple active failures associated with station blackout be in accordance with 10 CFR 50.63. The staff concludes that this requirement adequately resolves the issue of electric power supply failure for the essential service water system. Therefore, this DSER open issue is closed.

Effects of Intake Failure

In the DSER for Chapter 8, the staff recommended that EPRI address the effects of a potential intake structure failure and stated that consideration should be given to providing two separate and independent intake structures, as well as incorporating a cross-tie capability between plants with the attendant flexibility in recovery actions. The staff identified this as an open issue. In response to the open issue, EPRI stated that various arrangements for the ultimate heat sink (UHS) and intake structure had been considered. Among these were two UHSs and one UHS with two intake structures. However, EPRI has decided that the reference ALWR will have one passive cooling pond with one intake structure and be in accordance with Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants" (for comment). EPRI considered this design to be the simplest arrangement for several reasons, including minimizing the potential paths for covert penetration. This response is acceptable because the design will comply with the guidance in Regulatory Guide 1.27. Therefore, this DSER open issue is closed.

With regard to the acceptability of the Evolutionary Requirements Document relevant to the resolution of GI 51, as provided in Generic Letter (GL) 89-13, the staff concludes that the revisions of Chapter 8 meet most of the recommendations in Enclosure 1 of GL 89-13 (see also Section 3.3 of this chapter) and are acceptable.

Biofouling and Heat Exchanger Performance Testing

Provisions for the treatment of biofouling and performance testing of heat exchangers are discussed by the staff in Sections 3.2 and 3.3, respectively, of this chapter.

Generic Issue 130

GI 130, "Essential Service Water Pump Failures at Multiplant Sites," raised concerns about multi-plant units that have only two ESW pumps per plant with cross-tie capabilities. Accordingly, the specific core-melt frequencies and radiological consequences determined by the evaluation in GI 130 pertain only to the generic model multi-plant configuration with two ESW pumps per plant. Chapter 8 of the Evolutionary Requirements Document specifies that the system will have four ESW pumps per plant at multi-plant sites, and that the loss of one pump will not prevent adequate SWS flow for cooling all safety-related components. However, this resolves at most only 25 percent of the reliability problems discussed in GI 130. Both pumps in a given division are required to meet licensing-basis requirements, such as cold shutdown within 36 hours with a concurrent single failure, which defeats the purpose of the redundant division. In the DSER for Chapter 8, the staff concluded that EPRI should further examine the reliability of the ALWR ESW systems and should propose enhancements to the designs, if warranted. In the DSER, the staff identified this as an open issue.

EPRI responded that the SWS configuration and its reliability were reviewed and a probabilistic risk assessment (PRA) was performed for three different cooling water system configurations to compare their relative reliabilities. From these analyses, EPRI concluded that cross-ties were to be provided only if a compelling safety, operability, or availability need was demonstrated by the plant designer. EPRI decided that cross-ties would not be added to improve flexibility in recovery actions because the system design would increase in complexity. EPRI also stated that the PRA performed for the SWS indicated that the system reliability was sufficient to meet the overall targets for core-damage frequency.

The staff's evaluation of EPRI's requirements to address GI 130 is provided in Section 3.2.5.7 of Appendix B to Chapter 1 of this report. Therefore, this DSER open issue is closed.

Conclusion

The staff concludes that the design requirements in Section 5.2 of Chapter 8 for the ESWS do not conflict with the guidance in SRP Section 9.2.2, "Reactor Auxiliary Cooling Water Systems," and are, therefore, acceptable.

5.3 Nonessential Service Water System

The nonessential service water system (NESWS) will be a non-safety-related open system and will be designed to provide cooling water from the normal heat sink to the tube side of the TBCCWS heat exchangers, which in turn will cool various non-safety-related auxiliary components in the turbine and service buildings.

In Section 5.3 of Chapter 8, EPRI establishes the requirements for the design of the NESWS. Generally, these requirements ensure the NESWS will supply 100 percent of the flow required to service cooling loads at all times. The staff concludes that these requirements do not conflict with the guidance in SRP Section 9.2.2 and are, therefore, acceptable.

6 CIRCULATING WATER SYSTEM

The circulating water system (CWS) will be a non-safety-related open system designed to supply cooling water to the main steam turbine condensers in order to condense exhaust steam from the low-pressure turbines. This system will not serve any safety function under accident conditions and will not be required for keeping the reactor in a safe shutdown condition.

Section 6 of Chapter 8 of the Evolutionary Requirements Document establishes the requirements for the design of the CWS. The staff concludes that these requirements do not conflict with the guidance in SRP Section 10.4.5, "Circulating Water System," and are, therefore, acceptable.

7 HEAT SINKS

7.1 Definition and Scope

Section 7 of Chapter 8 of the Evolutionary Requirements Document provides the requirements for the PWR and BWR normal power heat sink and the ultimate heat sink. The normal power heat sink will be the final repository for heat rejected from the circulating water system (CWS) and nonessential service water system (NESWS). The ultimate heat sink will be the final repository for heat rejected from the essential service water system following an accident and during normal operation.

7.2 Normal Power Heat Sink

The primary function of the normal power heat sink will be to provide the source of cooling water to be used as circulating water and nonessential service water during power operation. This heat sink will be a non-safety-related open system. In Section 7.2 of Chapter 8 EPRI establishes the requirements for its design. In general, these requirements specify that the cooling towers and equipments are required to be capable of cooling the CWS and NESWS water to less than 100 °F during full-power operation under all weather conditions.

The staff concludes that the design requirements for the normal power heat sink do not conflict with the guidance in SRP Section 10.4.5, "Circulating Water System," and are, therefore, acceptable.

7.3 Ultimate Heat Sink

The primary function of the ultimate heat sink (UHS) will be to provide a reliable source of cooling water for use as essential service water during all modes of operations and accident conditions. The UHS will be a safety-related open system that will consist of one or more cooling ponds, makeup pumps, makeup intake structures, makeup and blowdown piping or channels, and the associated piping, valves, instrumentation, and controls.

In Section 7.3 of Chapter 8 of the Evolutionary Requirements Document, EPRI establishes the requirements for the design of the UHS. The key requirements include the following:

- A passive cooling pond is the preferred UHS for the ALWR. However, if required by specific site conditions, a natural body of water, spray ponds, or cooling towers may serve.
- The design of the UHS will be in accordance with Regulatory Guide 1.27.
- A blowdown pond will be provided as an intermediate discharge reservoir for blowdown from the UHS. The blowdown pond will be big enough to hold at least 24 hours of blowdown.
- The UHS facility will be seismic Category I.
- Makeup and blowdown lines will be provided with a throttling valve to adjust flow.

- Sufficient redundancy of makeup pumps will be provided so that makeup capabilities are not unduly reduced when one pump malfunctions. The need for safety-grade makeup water will be established in conjunction with establishing UHS water volume, as specified in Regulatory Guide 1.27.

- If sprays are used in the cooling pond, the spray systems will consist of one network for each essential service water division. The spray systems will function as required, assuming failure of one network.

- The UHS will be capable of performing its intended function during freezing weather. Means (such as recirculation of warm water) will be provided to ensure that flow is not reduced or lost as a result of ice buildup in the intake structures.

- The UHS water treatment and blowdown facilities will be designed on the basis of makeup water chemistry, environmental restrictions, evaporation rate, and draft loss.

Sections 1.3.5 and 7.3.2 of Chapter 8 of the Evolutionary Requirements Document indicate that a passive cooling pond is the preferred UHS.

In the DSER for Chapter 8, the staff stated that EPRI had committed to require that ALWR plant designs referencing the Evolutionary Requirements Document comply with the "Federal Guidelines on Dam Safety" when the reference pond is formed by a dam or a system of dikes or levees. The staff identified this as a confirmatory issue. The staff has verified that Section 7.3.2.2.1 now requires that the UHS facility be seismic Category I and, where applicable, be designed in accordance with the "Federal Guidelines on Dam Safety." Therefore, this DSER confirmatory issue is closed.

Section 7.3.1 of Chapter 8 of the original Evolutionary Requirements Document stated that the UHS will be capable of providing cooling water no warmer than 95 °F during normal full-power operating conditions based on 1-percent exceedance temperature for ambient conditions specified in Table 2-1 of Chapter 1 of the Evolutionary Requirements Document. In the DSER for Chapter 8, the staff stated that EPRI had committed to revise Chapter 1 to require that the maximum essential service water temperature for the ALWR standard plant design be based on 0-percent exceedance ambient temperature given in Table 2-1 of Chapter 1. The staff identified this as a confirmatory issue.

The staff has reviewed EPRI's revisions to Section 2.2.2 of Chapter 8 and Table 1.2-6 of Chapter 1 and has confirmed that the plant cooling water systems are required to be capable of supporting full reactor thermal output based on 0-percent exceedance ambient temperature as defined in Table 1.2-6 of Chapter 1. Therefore, this DSER confirmatory issue is closed.

The staff concludes that the design requirements in Chapter 8 for the UHS do not conflict with the guidance in SRP Section 9.2.5, "Ultimate Heat Sink," and are, therefore, acceptable.

8 CHILLED WATER SYSTEMS

The chilled water systems (CDWSs) will be closed-loop systems that will supply chilled water for the heating, ventilation, and air conditioning (HVAC) systems. The CDWS will be divided into two subsystems: an essential chilled water system* that will serve safety-related HVAC cooling loads and a non-essential chilled water system* that will serve non-safety-related HVAC cooling loads.

8.1 Essential Chilled Water System

In Section 8 of Chapter 8 of the Evolutionary Requirements Document, EPRI establishes the requirements for the design of the essential CDWS. The key requirements include the following:

- The system will consist of two (for PWRs) and three (for BWRs) totally independent divisions, each of which will have a refrigeration unit(s), pump(s), compression tank(s), and the associated piping, valves, instrumentation, and controls.
- Each safety-related division will be totally independent of and separated from the other division(s) both mechanically and electrically.
- Safety-related portions of the system will be protected from tornadoes, missiles, pipe whip, and flooding.
- Safety-grade makeup water will be provided to the essential CDWS.
- Instruments will be provided to indicate low water flow, low pressure, and high temperature of the water supply.

The staff concludes that these requirements appear to be appropriate for the handling of safety-related HVAC cooling loads by the system. The design requirements in the Evolutionary Requirements Document for the essential CDWS do not conflict with NRC requirements and are, therefore, acceptable.

8.2 Nonessential Chilled Water System

In Section 8 of Chapter 8 of the Evolutionary Requirements Document, EPRI states that the nonessential CDWS will be a centralized system that will supply various HVAC and process loads. However, if one centralized system for all buildings is impractical, separate systems can be provided for each building. The system(s) will consist of a single division with a compression tank, a minimum of two refrigeration units, a minimum of two chilled water pumps, instrumentation and controls, and associated equipment required for regulating flow.

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*Referred to by EPRI as "safety chilled water system," and "non-safety chilled water system," respectively.

In general, EPRI has established design requirements ensuring that the nonessential CDWS will produce, at all times, 100 percent of the design-basis chilled water flow to service division loads by the use of a single division. The staff concludes that these requirements are based on good engineering practice and are, therefore, acceptable.

9 FUEL POOL COOLING AND CLEANUP SYSTEM

Section 9.1.2 of Chapter 8 of the Evolutionary Requirements Document specifies that the fuel pool cooling and cleanup system (FPCCS) will perform the following functions:

- maintain the spent fuel pool temperature within the limits necessary to store and serve the spent fuel assemblies removed from the reactor vessel
- maintain the water level in the spent fuel pool within specified limits to ensure that the spent fuel pool assemblies remain cooled and covered at all times
- maintain the quality of the spent fuel pool water and makeup water within the specified limits of chemistry, radioactivity, and clarity
- maintain the water temperature, chemistry, and clarity within acceptable ranges for the in-containment refueling water storage tank (for PWRs) and the suppression pool (for BWRs)

EPRI indicates that the function of maintaining fuel pool cooling and level to within the safety limits is safety related, whereas the function of the pool cleanup to maintain water quality is not. In addition, BWR suppression pool cooling and PWR postaccident containment heat removal are addressed in Chapter 5 of the Evolutionary Requirements Document.

In Section 9.3.5 of Chapter 8, EPRI specifies that the electrical power for the FPCCS will be supplied from the normal station auxiliary power during normal plant operation. In the event of loss of all normal ac power, the electrical loads required for the system safety functions will be able to be connected to the onsite emergency ac power supply after a predetermined delay following a loss-of-coolant accident or a station blackout. In the rationale portion of this section, EPRI states that fuel pool cooling will not be required until some time after normal ac power is lost because of the large heat capacity of the fuel pool water. Because of the flexibility in system design that a plant designer has and because of the actions the plant operator will have to perform, the staff will evaluate the detailed system design and emergency operating procedures during its review of an individual application for FDA/DC to determine the timeframe in which the emergency power supply will be needed following a design-basis accident.

Section 9.3.2 of Chapter 8 of the original Evolutionary Requirements Document stated that the fuel pool cooling portion of the FPCCS will consist of two 100-percent-capacity, independent cooling divisions (same number of cooling divisions for PWRs and BWRs), each with one pump, one heat exchanger, and associated piping, valves, instrumentation, and controls, and that the heat exchangers will be cooled by the component cooling water system-nuclear steam supply system (CCWS-NSSS). In the DSER for Chapter 8, the staff concluded that because the FPCCS will interface with two of the three independent CCWS-NSSS divisions (for BWRs), the supplemental cooling for decay heat removal (DHR) should come from the division that is independent of the FPCCS. The staff identified this as an open issue.

To address this issue, EPRI revised Section 9.3.2.2 of Chapter 8 to require, in part, that this function be provided from the DHR division for which the component cooling water supply is independent of those divisions providing cooling water to the FPCCS. The rationale portion of the section has also been revised to state that since the FPCCS will interface with only two out of three independent CCWS-NSSS divisions, providing supplementary cooling from the third division will increase reliability. Section 4.2.1.5.1 of Chapter 8 has also been revised to state that Section 9.3.2.2 provides requirements for assigning of CCWS-NSSS divisions to the FPCCS and to the DHR system for supplementary cooling. The staff concludes that these revisions address its concern and are acceptable. Therefore, the DSER open issue is closed.

The staff concludes that the design requirements in Chapter 8 for the FPCCS do not conflict with the guidance in SRP Section 9.1.3, "Spent Fuel Pool Cooling and Cleanup System," and are acceptable.

10 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 8 of the Evolutionary Requirements Document for the design of plant cooling water systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the plant-specific design, operation, and arrangement of the plant cooling water will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the Standard Review Plan (NUREG-0800), or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 8 specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose plant cooling water systems will perform as designed and will have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A, Chapter 8 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
GENERIC SAFETY AND LICENSING ISSUES

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address the resolution of generic safety issues in Appendix B of each chapter. In the DSER for Chapter 8 of the Evolutionary Requirements Document, the staff evaluated EPRI's requirements to address the resolution of the following generic issues:

- B-32, "Ice Effects on Safety-Related Water Supplies"
- 51, "Proposed Requirements for Improving Reliability of Open Cycle Service Water Systems"
- 130, "Essential Service Water Pump Failures at Multi-Plant Sites"
- B-29, "Effectiveness of Ultimate Heat Sinks"

In the DSER for Chapter 8, the staff identified open issues associated with Generic Issues 51 and 130. In Revision 1 of the Evolutionary Requirements Document, submitted by letter dated September 7, 1990, EPRI relocated its requirements to address generic safety issues that were unresolved as of January 1. 1990, to Appendix B to Chapter 1. As a result, a number of generic safety issues that were addressed in the original Evolutionary Requirements Document are no longer addressed. The staff has provided its evaluation of EPRI's requirements to address generic safety issues in Appendix B to Chapter 1 of this report and has also documented its closure of open and confirmatory issues associated with generic safety issues no longer addressed by EPRI. Therefore, the DSER open issues associated with Generic Issues 51 and 130 are closed.

CHAPTER 9, "SITE SUPPORT SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 9, "Site Support Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 9 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering Nuclear Power; Bechtel Power Corporation; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Sargent and Lundy Engineers; Stone and Webster Engineering Corporation; Westinghouse Electric Corporation; and EPRI.

On January 1?, 1989, EPRI submitted the original version of Chapter 9 of the Evolutionary Requirements Document for staff review. By letters dated March 22, April 28, June 8, September 14, and November 28, 1989, the NRC staff requested that EPRI supply additional information. EPRI provided the information in its responses dated August 18, October 19, and December 22, 1989, and January 18, 1990. Topic papers in Appendix B of the original version of this chapter were relocated to Appendix B of Chapter 1.

On January 15, 1991, the staff issued its DSER for Chapter 9 of the Evolutionary Requirements Document. On April 9, 1991, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 9, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 9, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 9 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 9

Chapter 9 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the site support systems.

The key topics addressed in the Chapter 9 review include EPRI-proposed design requirements for

- fire protection systems
- environmental monitoring system
- site security system
- decontamination facilities

- compressed air and gas systems
- heating, ventilating, and air conditioning system
- laboratories

1.3 Policy Issues

During its review of Chapter 9 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 9 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) human factors considerations in the design of control room indicating systems (2.2.5)

(2) independence of ventilation systems inside the containment (3.3.1)

(3) requirements for smoke-removal capability (3.3.1)

(4) human factors considerations in the design of the fire protection system (3.4.11)

(5) sabotage considerations for the control room (5.1)

(6) effects of instrument air supply problems on safety-related equipment (Generic Letter 88-14) (7.1)

(7) design of air filtration systems (8.2.1)

(8) structural design of heating, ventilating, and air conditioning (HVAC) system (8.2.1)

(9) charcoal filters in air filtration systems (8.2.1)

(10) control room capacity following design-basis accident (8.2.2)

(11) determination of airborne iodine concentration during an accident (Item III.D.3.3 of NUREG-0737) (9)

Confirmatory Issues

(1) use of radiation-damage-resistant materials in high-radiation areas (2.2.4 and 8.2.1)

(2) control room cable fires (3.4.9)

(3) use of seismically sensitive relays in fire protection systems (3.4.13)

(4) design enhancements for sabotage protection (5.1)

(5) guidance designation of vital equipment (5.2.1)

(6) insider sabotage vulnerability analysis (5.2.2 and Appendix B)

(7) inaccessibility of cable and piping runs connecting two protected areas (5.2.4)

(8) installation of security door hardware (5.2.5)

(9) alarm assessment coverage of interior of intrusion detection system (5.2.7)

(10) use of hand-held radios in plant buildings (5.2.11)

(11) backup power for security lighting (5.2.12)

(12) use of duct wrap or other material for protecting ventilation system penetrations of fire barriers (8.2.1)

(13) operability of safety-related systems in areas with shared HVAC systems (8.2.1)

(14) bullet resistance of control room (8.2.2)

(15) resistance to penetration of an unalarmed grating (8.2.4)

(16) potential for insider sabotage (Appendix B)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All outstanding issues identified in the DSER for Chapter 9 of the Evolutionary Requirements Document have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.9.V-1 fire protection review (3)

E.9.V-2 fire hazard analysis (3.2.2)

E.9.V-3 smoke removal capability (3.3.1)

E.9.V-4 security hardware on fire doors (3.3.1)

E.9.V-5 separation of redundant shutdown equipment in the containment (3.3.1)

E.9.V-6 control room cable fires (3.4.9)

E.9.V-7 security area devitalized during unit shutdown (5.1)

E.9.V-8 operability of safety-related systems in areas with shared HVAC systems (8.2.1)

E.9.V-9 criteria for design of HVAC ductwork (8.2.1)

E.9.V-10 HVAC design for PWR auxiliary building (8.2.5 and 8.4.4)

E.9.V-11 HVAC design for miscellaneous areas (8.2.6)

E.9.V-12 charcoal filters in containment purge system (Branch Technical Position CSB 6-4, NUREG-0800) (8.4.2)

E.9.V-13 design, equipment, and instrumentation for laboratories (9)

E.9.V-14 determination of airborne iodine concentration during an accident (Item III.D.3.3 of NUREG-0737) (9)

2 POLICY STATEMENTS AND KEY REQUIREMENTS

2.1 Policy Statements

Chapter 9 of the Evolutionary Requirements Document specifies the requirements proposed by EPRI for the fire protection system; environmental monitoring system; site security system; decontamination system; compressed air and gas systems; heating, ventilating, and air conditioning (HVAC) system; and laboratories. Section 1 of Chapter 9 contains those policies established by the ALWR Utility Steering Committee related to the design approach to be used in the development of the security, fire protection, and compressed air and gas systems for both the BWR and PWR designs.

Section 1.4.1 of Chapter 9 states that EPRI's approach to sabotage protection emphasizes sabotage prevention rather than mitigation. The Evolutionary Requirements Document states that resistance to sabotage will be provided through rugged reinforced-concrete external walls and internal barriers that will restrict access. Further resistance will be provided through physically separated, redundant safety systems that will provide high reliability for the prevention of core damage or the mitigation of the consequences of accident sequences. EPRI further states that the plant arrangement and the access control features of the plant security system will be compatible with the need to accommodate personnel traffic with minimum delay during normal plant operation and maintenance, and to not impede access or egress under emergency conditions.

Section 1.4.2 of Chapter 9 states that ALWR plants will be equipped with fire protection systems that will, with high reliability, be capable of detecting and suppressing fires that could threaten the health and safety of the public and operating personnel.

Section 1.4.3 of Chapter 9 states that ALWR plants will have the capability to accomplish essential safety functions from control panels external to the control room, should evacuation of the control room be required because of fire or other events, or should a fire damage the control room circuitry for safe shutdown systems.

Section 1.4.4 of Chapter 9 states that ALWR plants will include a compressed air and gas system (CAGS) that will minimize air leakage, contamination of air supplies, blockage of air lines, and equipment malfunction. The CAGS will not be designed to meet safety-grade criteria. EPRI states that safe shutdown capability will be ensured by designing equipment served by the CAGS to maintain or assume a safe position on loss of the air supply.

2.2 Site Support Systems - Common Requirements

Section 2 of Chapter 9 of the Evolutionary Requirements Document establishes the top-tier requirements applicable to all evolutionary ALWRs, including PWRs and BWRs. Evolutionary designs are the next-generation, improved versions of existing facilities (approximately 1300 MWe). The following sections give the staff's evaluations of the key requirements in the Evolutionary Requirements Document common to the site support systems.

2.2.1 Operability and Maintainability

Section 2.2.1 of Chapter 9 states that components of site support systems will be of standardized, generic design wherever possible and will be located so as to facilitate testing and maintenance. EPRI indicates that equipment arrangement will provide adequate space for access and replacement. Cableways will allow for ease of access and expansion. Components will be labeled with a unique number and name, consistent with plant drawings. HVAC systems will be capable of maintaining environmental conditions that are compatible with human comfort and with equipment installed in the rooms and compartments served. EPRI states that the plant designer will ensure that information on systems design is retained and available for later use in the preparation of procedures.

2.2.2 System Interactions

Section 2.2.2 of Chapter 9 specifies that, to minimize potential system interactions, ALWR site support systems will not be interconnected with each other or with other systems. Compressed air and gas systems will not be interconnected. Fire protection systems will be designed so that in the event of a fire, assuming no single failures, at least one division of safe shutdown equipment will be operable. Failure to operate or inadvertent operation of non-safety-related systems will not prevent the operation and proper functions of safety-related systems.

2.2.3 Safety-Related Plant Equipment

Section 2.2.3 of Chapter 9 states that all air-operated safety-related equipment, accumulators, controls, etc., will be designed for fail-safe operation and will not require instrument air supply for safe shutdown. All engineered safety feature systems will be testable to ensure safe operation in the event of a loss or a gradual reduction of the instrument air supply.

2.2.4 Radiation Exposure

Section 2.2.4 of Chapter 9 requires that equipment and facilities subject to radioactive contamination from radiological incidents or normal plant operations be designed to facilitate decontamination and/or to prevent the spread of contamination. The use of curbs around equipment and tanks, floors sloped to drains, coatings that can be decontaminated, minimization of irregular surfaces, and component accessibility are some of the design features that will be used to ensure that radiation exposure will be as low as is reasonably achievable. The HVAC system will be designed to minimize the potential exposure of personnel to radioactivity from airborne contamination. To minimize time spent by personnel in radiation areas and to facilitate decontamination, suitable facilities will be located to support maintenance and repair activities performed in high-radiation areas and to support decontamination activities. The staff concludes that the above features to minimize personnel exposure and to prevent the spread of contamination comply with the guidelines of Regulatory Guide 8.8, "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Reasonably Achievable."

Section 2.2.4 of Chapter 9 does not address the use of radiation-damage-resistant materials in high-radiation areas. Because EPRI committed to address this issue in future revisions of the Evolutionary Requirements Document, the staff identified this as a confirmatory issue in the DSER for Chapter 9. Sections 5.5.1 and 12.3.2.1.9 of Chapter 1 have been revised to state that the specification of non-metallic parts must consider radiation hardening as well as other environmental conditions to maximize their service life and ensure that they require a minimum of maintenance. The staff has verified that EPRI has addressed the issue of radiation-damage-resistant materials in the Evolutionary Requirements Document. Therefore, this DSER confirmatory issue is closed.

2.2.5 Information Management

Section 2.2.5 of Chapter 9 states that human factors will be considered in the design of control room indicating systems. Data management systems for environmental monitoring will be capable of sharing data with other data base systems and will have graphical output capability.

Because EPRI had not provided additional information regarding its general approach to incorporating human factors considerations into the Evolutionary Requirements Document, the staff identified an open issue regarding the design of control room indicating systems in its DSER for Chapter 9. The staff's evaluation of EPRI's requirements to address human factors considerations related to all portions of the Evolutionary Requirements Document is provided in Appendix D to Chapter 10 of this report. Therefore, the DSER open issue concerning human factors considerations in the design of control room indicating systems in Section 2.2.5 of Chapter 9 is closed.

3 FIRE PROTECTION SYSTEMS

Review Criteria

Fire protection requirements for nuclear power plants are provided in 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 3, and in 10 CFR 50.48.

GDC 3 governed fire protection for nuclear power plants and was considered adequate until the fire at the Browns Ferry plant on March 22, 1975. This remains the most serious fire to date in commercial U.S. nuclear power plants. A committee was formed to investigate the fire and to make recommendations on the basis of its findings. One of the recommendations by the committee was that specific fire protection guidance should be developed that would supplement the general requirements in GDC 3. The staff published the specific guidance in Branch Technical Position (BTP) APCSB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants," for new plants docketed after July 1, 1976 (revision of Section 9.5.1 of NUREG-75/087, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants - LWR Edition," dated May 1, 1976). In August 1976, the staff published Appendix A to BTP APCSB 9.5-1 to provide specific fire protection guidance for those plants that had docketed their applications for construction permits before July 1, 1976. All licensees of operating plants and applicants of plants in various stages of design and construction were asked to review their plants against the guidance in Appendix A to BTP APCSB 9.5-1 and to identify areas of compliance and noncompliance. For identified items of noncompliance, each licensee and applicant was asked to propose modifications to achieve compliance or to show why compliance was not required.

By mid-1979, most plants had complied with most of the provisions of Appendix A to BTP APCSB 9.5-1. However, 18 open issues existed in various combinations at 33 operating plants. The staff then developed 10 CFR 50.48 and Appendix R to 10 CFR Part 50 (published on November 19, 1980, and effective on February 17, 1981) as a means of resolving the remaining 15 open issues (reduced from the original 18 open issues) at plants licensed to operate before January 1, 1979. In addition, the Commission considered sections of Appendix R to be so important that their provisions were required for all plants even if the staff had previously approved the design in those areas. The three sections of Appendix R that applied to all plants were III.G ("Fire Protection of Safe Shutdown Capability"), III.J ("Emergency Lighting"), and III.O ("Oil Collection System for Reactor Coolant Pump"). After 10 CFR 50.48 and Appendix R to 10 CFR Part 50 were published, the staff revised BTP APCSB 9.5-1, which became BTP CMEB 9.5-1 (July 1981, as part of NUREG-0800 SRP) to include the provisions of Appendix R so as to give additional guidance to those plants that had docketed their applications for construction permits before July 1, 1976, and that were still being completed and were preparing for operating licenses.

It is important to note that this subsequent fire protection guidance for operating plants, as well as for plants still being constructed, is derived and represents deviations from the original guidance (BTP APCSB 9.5-1, May 1, 1976) developed for new plants. The intention has always been that when any advanced reactor designs were proposed, fire protection would be provided on the basis of the best technology available, not on the basis of methods allowed for plants already operating or in advanced stages of design and construction.

On this basis, the staff evaluated the criteria in the Evolutionary Requirements Document for the fire protection system against the criteria of SRP Section 9.5.1 (BTP CMEB 9.5-1, July 1981) and supplemental guidance issued by the Commission. Three examples of such supplemental guidance are (1) Generic Letter 81-12, which contains information on safe shutdown methodology; (2) Generic Letter 86-10, which contains important technical information, such as conformance with National Fire Protection Association codes and standards; and (3) the Commission's staff requirements memorandum (SRM) dated June 26, 1990.

In SECY-90-016, "Evolutionary Light Water Reactor Certification Issues and Their Relationship to Current Regulatory Requirements," the staff concluded that fire issues that have been raised through operating experience and through the External Events Program must be resolved for evolutionary ALWRs. To minimize fire as a significant contributor to the likelihood of severe accidents for evolutionary advanced reactors, the staff proposed that the Commission enhance NRC's current guidance. In its SRM of June 26, 1990, on SECY-90-016, the Commission approved the staff's position regarding review criteria for fire protection design, as discussed in SECY-90-016 and supplemented by the staff's April 27, 1990, response to comments by the Advisory Committee on Reactor Safeguards. The designers of standard plants must demonstrate that safe shutdown of their plants can be achieved, assuming that all equipment in any one fire area has been rendered inoperable by fire and that reentry to the fire area for repairs and for operator actions is not possible. The control room is excluded from this approach, subject to the need for an independent alternative shutdown capability that is physically and electrically independent of the control room. Fire protection for redundant shutdown systems in the reactor containment building should ensure, to as great an extent as possible, that one shutdown division will be free of fire damage. Consideration should be given to safety-grade provisions for the fire protection systems to ensure that the remaining shutdown capabilities are protected. In addition, it should be demonstrated that smoke, hot gases, or fire suppressants will not migrate into other fire areas to the extent that safe shutdown capabilities, including operator actions, could be adversely affected. It is anticipated that this will be accomplished, in part, by providing separate ventilation systems for redundant trains. The staff evaluated the criteria in the Evolutionary Requirements Document for the fire protection system against these criteria. The staff will review specific design details during its review of an individual application for FDA/DC.

General Evaluation

EPRI has generally followed NRC's concept of defense-in-depth with regard to fire protection. The three steps of defense-in-depth and EPRI's implementation of these steps follow:

(1) Reduce the possibility of fire starting in the plant - EPRI used fire-resistant and fire-retardant materials in its design to minimize and isolate fire hazards.

EPRI will use either low-voltage or fiberoptic multiplexed circuits in its design, thus eliminating the need for cable spreading rooms and substantially reducing the amount of combustible cable insulation and higher voltage ignition sources in the control room.

(2) Detect and suppress fire promptly - EPRI has provided automatic detection and a suitable mix of automatic and manual fire suppression capability in its design.

(3) Ensure that any fire that might occur will not prevent safe shutdown of the plant even if fire detection and suppression efforts should fail - EPRI has attempted to ensure this. A detailed staff evaluation of the effectiveness of this approach is provided in the following sections.

The fire protection program described by EPRI is intended to protect safe shutdown capability, prevent the release of radioactive materials, minimize property damage, and protect personnel from injury as a result of fire.

EPRI considered not only the three aspects of defense-in-depth outlined above, but also such features of general plant arrangement as access and egress routes, equipment locations, structural design features that separate or isolate redundant safety-related systems, floor drains, ventilation, and construction materials.

EPRI has used applicable National Fire Protection Association codes and standards in its design and layout of the facility. An ALWR designer or applicant will be required to identify any deviations from these codes and standards and to describe in the fire hazard analysis the deviations and measures taken to ensure that equivalent protection is provided for a plant-specific design.

3.1 System Definition

EPRI states that the scope of Section 3 of Chapter 9 of the Evolutionary Requirements Document encompasses the systems required for protecting evolutionary ALWRs from fire, including assurance that the plant can achieve and maintain safe shutdown in the event of a fire. In addition, EPRI states that the fire protection systems will ensure personnel safety, protection of property, and continuity of power production. Systems included in Section 3 of Chapter 9 are fire and smoke detection systems and automatic and manual fire suppression systems. Building structural and physical arrangement features to enhance fire protection are evaluated in Chapter 6 of this report. The staff's evaluation of the effect of fire protection features on electric power systems is provided in Chapter 11 of this report.

3.2 Performance Requirements

3.2.1 General

Section 3.2.1 of Chapter 9 of the Evolutionary Requirements Document states that the plant fire protection system will be designed, installed, and tested in accordance with SRP Section 9.5.1, "Fire Protection Program," which includes BTP CMEB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants," July 1981.

3.2.2 Fire Hazard Analysis

Section 3.2.2 of Chapter 9 states that the plant designer will perform a fire hazard analysis, as described in SRP Section 9.5.1, for systems, structures, and components important to safety.

In a letter dated June 8, 1989, the staff stated that it was concerned about the details of the fire hazard analysis and how it was to be performed. In its response dated October 19, 1989, EPRI stated that the details of the fire hazard analysis were beyond the scope of the Evolutionary Requirements Document. Although the staff considers this exclusion acceptable for the Evolutionary Requirements Document, it will review the fire hazard analysis proposed for an individual plant during its review of an application for FDA/DC and the final licensing review. As stated previously, the staff will require that fire protection for advanced reactors be provided on the basis of the best technology available. Using only the guidance of SRP Section 9.5.1 when developing the fire hazard analysis will not be sufficient for an advanced reactor design.

3.3 System Features

3.3.1 Protection of Redundant Safety Divisions

Section 3.3.1 of Chapter 9 of the original Evolutionary Requirements Document stated that safe shutdown equipment will be protected from fire damage by at least one of the following methods, in order of preference: (1) 3-hour-fire barriers, (2) 1-hour-fire barriers combined with fire detectors and automatic fire suppression, or (3) 20-foot separation between redundant trains combined with fire detectors and automatic fire suppression.

In a letter dated June 8, 1989, the staff stated its concern that fire protection measures that had been found acceptable for existing LWRs because of exigencies of existing designs that could not be readily changed would be proposed for ALWRs. As discussed above, it is the staff's position that enhanced fire protection should be provided for ALWRs. The staff also expressed concern that smoke, hot gases, and fire suppressants could migrate to other fire areas to the extent that they could affect safe shutdown capability, including operator actions.

In its letter dated October 19, 1989, EPRI responded that it would

- comply with the provisions of SRP Section 9.5.1 (including guidance to ensure that one division in the containment will be free from fire damage and that smoke, hot gases, etc., will not migrate to other areas to the extent that they could affect safe shutdown capability)
- provide enhanced fire protection by revising Section 2.3.2 of Chapter 5 and Section 3.3.1.1 of Chapter 9 to eliminate the provision calling for 20-foot separation as a means of protecting redundant safe shutdown systems outside the containment.

The commitment by EPRI to use 3-hour-fire barriers for separating safe shutdown systems outside the containment complies with the review criteria and is acceptable.

In Section 8.1.2 of Chapter 9, EPRI states that one of the functions of the heating, ventilating, and air conditioning (HVAC) system is to prevent the migration of smoke, hot gases, and fire suppressants into other fire areas to the extent safe shutdown capabilities, including operator actions, could be adversely affected. The staff identified this as an open issue in the DSER for Chapter 9. The staff also identified the lack of smoke-removal considerations as an open issue.

In Section 8.2.2.1.11 of Chapter 9, EPRI requires that the main control room HVAC system be capable of removing smoke from the control room after a fire and that it be in accordance with National Fire Protection Association (NFPA) 90A. Similar requirements are contained elsewhere in Chapter 9 for other specific areas. With these requirements, EPRI has committed to use the HVAC system for removing smoke from specific areas as a means of satisfying the smoke control provisions of NRC fire protection guidance. Although the staff will evaluate specific details of design, installation, and operation of the HVAC systems functioning in the smoke removal mode during its review of individual applications for FDA/DC, it concludes that these requirements are acceptable. Therefore, these DSER open issues are closed.

In a letter dated June 8, 1989, the staff requested that EPRI provide a description of how security hardware will be installed on fire doors so as to not compromise the fire rating of the doors. In its October 19, 1989, letter, EPRI responded that this description entails detailed engineering instructions that are beyond the scope of the Evolutionary Requirements Document. Therefore, the staff will review details of the installation of security hardware on fire doors during its review of an individual application for FDA/DC to ensure that the fire rating of the doors has not been compromised.

With respect to fire protection of safe shutdown systems inside the containment, EPRI has generally excluded fire protection methods for systems inside the containment. The staff recognizes the need for open communication between compartments inside the containment so that pressure following a high-energy line break can be relieved and equalized. Therefore, the use of structural walls inside the containment as fire barriers to separate safety-related systems (cabling, components, and equipment), even though such walls may not fully enclose the equipment requiring separation, is acceptable in intent. However, care must be taken in actual system layout to ensure that line-of-sight exposure between components requiring separation does not exist and that a sufficient labyrinth exists between the separated components to ensure that fire does not spread. Since the containment is considered to be a single fire area, the separation of redundant shutdown equipment, including associated cables, should be such that to the extent practicable one shutdown division will remain free of fire damage. The staff will review an individual application for FDA/DC to ensure these considerations are included in the design.

3.3.2 Component Replacement

Section 3.3.2 of Chapter 9 states that the fire protection equipment will be designed and installed to facilitate replacement necessitated by aging, early failure, or obsolescence.

3.3.3 Extended Fire Protection Coverage

Section 3.3.3 of Chapter 9 states that for purposes of investment protection, the turbine-generator and associated areas described in NFPA 803, "Fire Protection for Light Water Nuclear Power Plants," will be protected in accordance with NFPA 803. All areas of the plant provided with automatic fire suppression systems will also be provided with manual backup fire suppression capability. Areas not required to have automatic fire suppression systems will be provided with manual fire suppression capability where necessary, on the basis of the fire hazard analysis. In areas where equipment contains a sufficient quantity of oil to warrant a fixed fire suppression system, the system will be designed in accordance with NFPA 13, "Standard for the Installation of Sprinkler Systems." In areas where the fire hazard does not warrant a fixed suppression system, automatic fire detection will be provided. Automatic fire suppression systems will be provided for warehouses containing high-value equipment and combustible materials that are critical for power generation or that constitute a fire hazard for other buildings important to power generation.

Section 3.3.3.5 of Chapter 9 states that hydrants will be installed in sufficient number to provide (1) two streams for every part of the interior of any building not covered by standpipe protection and (2) hose stream protection for every part of each building. Each hydrant will have its own isolation valve.

Ventilation filters that collect combustible material and are potential fire hazards will be considered in the fire hazard analysis. Fire suppression will be provided as necessary, in accordance with Section 3.3.3.6 of Chapter 9 of the Evolutionary Requirements Document.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4 <u>Component Features</u>

3.4.1 Preaction Sprinklers

Section 3.4.1 of Chapter 9 of the Evolutionary Requirements Document specifies that preaction sprinkler systems will be used where the undesirable consequences of leakage or inadvertent operation are great.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.2 Fire Pumps

Section 3.4.2 of Chapter 9 states that two or more fire pumps will be provided so that 100 percent of the design capacity of fire pumps will be maintained should the largest pump be inoperable or should offsite power be lost. Automatic fire pump start controls will be provided to maintain pressure in the fire main.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.3 Water Supply

Section 3.4.3 of Chapter 9 states that fire protection water will be from a treated, filtered, dedicated source to reduce contamination by biological fouling and debris. One of the sources of fire water supply, including storage, pump suction piping, the pump and the pump discharge piping to the fire main, and the portion of the fire main necessary for manual backup protection of safe shutdown capability following an earthquake will be designed to seismic Category I criteria.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.4 Pressure Maintenance Pump

Section 3.4.4 of Chapter 9 states that pressure in the fire main will be maintained at least 10 psig above the set pressure for automatic starting of the fire pumps. A hydropneumatic system will not be used for this purpose. Although other methods may be used, EPRI recommends the use of a jockey pump.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.5 Halon and Carbon Dioxide

Section 3.4.5 of Chapter 9 states that the use of carbon dioxide fixed flooding systems will be minimized because of potential hazards to personnel, thermal shock effects, environmental concerns, and the need for the compartment boundary to be leaktight. Halon has not been included in EPRI's ALWR design because of environmental concerns. EPRI states that these systems, where used, will be provided with air test connections for surveillance of nozzles and headers. Seismically sensitive relays are prohibited in these systems.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.6 Cable Tray Fires

Section 3.4.6 of Chapter 9 states that controls for sprinkler systems protecting cable trays will be sufficiently sensitive to actuate in the event of a cable tray fire.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.7 Portable Extinguishers

Section 3.4.7 of Chapter 9 states that portable fire extinguishers will not be located in highly radioactive areas unless the fire hazard analysis indicates that a specific need exists. These fire extinguishers will be located in unobstructed areas and will be readily accessible to highly radioactive areas. Hose stations will be located outside highly radioactive areas except as necessary to provide a minimum of one hose stream, with 100 feet of hose, to any location that contains or could present a hazard to safety-related equipment.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.8 Fire Detectors

Section 3.4.8 of Chapter 9 states that the specific combustion products, type of hazard, fire load, and the effects of humidity, air velocity, temperature, air pollution, radiation, and pressure will be considered when selecting the type of fire detector to be used for each application and the location of detectors. Periodic maintenance requirements and personnel exposure also will be considered when selecting the location of detectors.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.9 Control Room Cables

Section 3.4.9 of Chapter 9 states that cable installations in the control room underfloor or ceiling spaces will be designed to eliminate the need for automatic fire suppression in these areas or in raceways.

In a letter dated June 8, 1989, the staff stated that it was concerned about the potential for fire and attendant fire suppression activities in the control room underfloor and ceiling spaces. Specific concerns included (1) the firefighting medium that will be used and (2) the possible unacceptable effects of firefighting activities and fire suppressants on equipment in the control room.

By letter dated October 19, 1989, EPRI committed to revise Section 3.4.9 of Chapter 9 of the Evolutionary Requirements Document to require that access be provided to permit the use of manual fire extinguishers to fight fires in any portion of the control room underfloor or ceiling spaces containing any significant fire load. The staff identified this as a confirmatory issue in the DSER. The staff has verified that EPRI has made the appropriate revisions to Sections 1.4.3 and 3.4.9 of Chapter 9. EPRI has specified additional design approaches intended to minimize the risk of fire in these areas of the control room, including the following:

- limiting cables to lighting, smoke detectors, and other similar services in the ceiling spaces

* reducing the amount of electrical cables, limiting horizontal cable runs, using only 4-inch or smaller steel conduits, using concrete or steel cable troughs, and using fire breaks at 20-foot intervals in the underfloor space.

The staff concludes that the requirements of Section 3.4.9 are now consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable. Therefore, this DSER confirmatory issue is closed. However, the staff will review the specific details of the control room cabling during its review of an individual application for FDA/DC.

3.4.10 Corrosive Fire Agents

Section 3.4.10 of Chapter 9 states that potential corrosive effects of fire suppression agents on plant equipment will be considered in the selection of agents and in the design of exposed equipment.

The staff concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.11 Human Factors

Section 3.4.11 of Chapter 9 states that human factors will be considered in the design of detection and alarm panels.

Because EPRI had not provided additional information regarding its general approach to incorporating human factors considerations into the Evolutionary Requirements Document, the staff identified an open issue regarding fire protection in its DSER for Chapter 9. The staff's evaluation of EPRI's requirements to address human factors considerations related to all portions of the Evolutionary Requirements Document is provided in Appendix D to Chapter 10 of this report. Therefore, the staff concludes that the DSER open issue concerning human factors considerations in the requirements for fire protection in Section 3.4.11 of Chapter 9 is closed.

3.4.12 Diesel Generator Areas

Section 3.4.12 of Chapter 9 states that diesel generator areas will be protected with automatic foam sprinklers and that foam hose reels and carbon dioxide hand-held fire extinguishers will also be provided in these areas.

In a letter dated June 8, 1989, the staff requested that EPRI justify the selection of foam as a fire suppressant in the diesel generator area, because foam could damage equipment.

In its October 19, 1989, letter, EPRI stated that the foam would be delivered by a preaction automatic sprinkler system. Therefore, foam would be delivered only where fire had already resulted in the opening of individual sprinkler heads. Since a fire will rapidly damage nearby equipment, rapid extinguishment of the fire is first priority. Possible collateral damage to the diesel generator due to foam discharge is a secondary concern because without prompt extinguishment, the fire will result in total damage and loss of the diesel generator and its associated equipment. EPRI considers foam to be more reliable than carbon dioxide because of the problem of fire reflashing and difficulties in maintaining area boundaries gas tight will be eliminated.

The staff agrees with EPRI's response and concludes that the requirements of this section are consistent with the enhanced fire protection criteria discussed above and are, therefore, acceptable.

3.4.13 Seismically Sensitive Relays

In a letter dated August 16, 1989, EPRI stated that Chapter 9 would be revised by adding a requirement that seismically sensitive relays not be used in the fire protection, detection, alarm, and suppression systems. This was identified as a confirmatory issue in the DSER for Chapter 9. Section 3.4.5.3 of Chapter 9 has been added and requires that fire protection suppression system relays for carbon dioxide fixed flooding systems not be seismically sensitive. Although nothing is said here, or in any other section of Chapter 9, concerning relays in other fire protection-related systems, the staff interprets this requirement as applying to any fire protection system in which relay failure due to seismic activity could lead to unacceptable consequences. On this basis, the staff concludes that EPRI has met its commitment. Therefore, this DSER confirmatory issue is closed.

4 ENVIRONMENTAL MONITORING SYSTEM

4.1 Scope and Functions

Section 4.1 of Chapter 9 of the Evolutionary Requirements Document states that the environmental monitoring system (EMS) will include the systems and equipment that will provide the data necessary for controlling plant releases and for assessing the plant effluent releases to the environment. Included will be the systems and equipment for monitoring meteorological data, water quality, solid waste, and offsite radiation levels. The information from the monitoring systems will be used (1) before plant construction to establish a baseline for licensing purposes, (2) to predict the effects of radiological effluents on the surrounding environment, and (3) to collect data needed to assess the effect of cooling water discharges and cooling tower blowdown and drift.

The staff's evaluation of the plant meteorological system and the water quality monitoring requirements follows. Its evaluation of the requirements for radiation monitors, including the monitoring system for the solid radioactive waste processing system, is provided in Chapter 12 of this report.

4.2 Performance Requirements

4.2.1 Meteorological Data

Section 4.2.1 of Chapter 9 of the Evolutionary Requirements Document states that onsite instrumentation will be provided for monitoring wind speed and wind direction and the vertical temperature gradient. Redundant equipment will be provided as necessary to achieve a 90-percent joint annual recovery of wind-speed, wind-direction, and atmospheric stability parameters in accordance with Regulatory Guide 1.23, "Onsite Meteorological Programs (Safety Guide 23)." Sampling and recording intervals will be in accordance with this regulatory guide. Offsite equipment will be provided as necessary. Provisions will be made for collecting a minimum of 12 and preferably 24 months of data. Real-time, continuous display of monitored variables will be provided in the control room and emergency response facilities.

With regard to onsite meteorological instrumentation, the Evolutionary Requirements Document specifies the use of Regulatory Guides 1.23 and 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants To Access Plant and Environs Conditions During and Following an Accident."

The staff finds that the use of Regulatory Guides 1.23 and 1.97 for defining the system's capability to monitor wind speed and wind direction and to determine atmospheric stability is acceptable.

4.2.2 Water Quality Data

Section 4.2.2 of Chapter 9 states that equipment will be provided to monitor flow, water or tide level, temperature, total dissolved solids, total suspended solids, total dissolved oxygen, conductivity, pH, and intake and discharge chlorine levels including that of cooling tower blowdown. The staff concludes that these parameters have been found useful in assessing water quality at reactor sites.

4.3 System Features

4.3.1 Primary Meteorological Tower

Section 4.3.1 of Chapter 9 of the Evolutionary Requirements Document states that the primary meteorological tower will have instrumentation sensors at the 10-meter level and at a height approximately the level of routine radionuclide release from the plant vent. The equipment at the 10-meter elevation will monitor the standard deviation of vertical wind speed as a means of measuring atmospheric stability. Visibility, dew point, and solar radiation measurements will be provided if necessary to support cooling tower operation. A third set of sensors will be provided above the routine release height, if the height of the vent is significantly greater than 60 meters.

4.3.2 Supplementary Towers

Section 4.3.2 of Chapter 9 states that an additional tower(s) will be provided if necessary because of site topography, local meteorology, and building conditions.

4.3.3 Siting

Section 4.3.3 of Chapter 9 states that towers will be sited to provide representative measurements. Generally, surrounding obstacles will be located at a distance at least 10 times their height.

4.3.4 Control Locations

Section 4.3.4 of Chapter 9 states that controls for meteorological monitoring instrumentation will be located in a weatherproof, lightning-protected building. The building will be provided with heating, ventilation, and air conditioning as necessary to meet the environmental criteria of the enclosed equipment.

4.3.5 Weather Protection

Section 4.3.5 of Chapter 9 states that sensors, instrumentation, and cabling will be provided with lightning, power surge, and ice protection. Instrument cables will be shielded. At sites on coastal locations, sensors will be provided with a means of preventing salt buildup.

4.3.6 System Power Source

Section 4.3.6 of Chapter 9 states that the EMS will be energized from a noninterruptible power source from the onsite ac system and will comply with Regulatory Guide 1.97. Offsite EMS equipment will be provided with backup battery power.

4.4 Instrumentation and Control

4.4.1 General Requirements

Chapter 10 of the Evolutionary Requirements Document specifies the general requirements applicable to EMS instrumentation and controls, which are evaluated in Chapter 10 of this report. Standard, commercially available equipment will be used.

4.4.2 Generic Instrumentation

Section 4.4.2 of Chapter 9 states that equipment of generic design will be used where possible to reduce variation in operation, calibration, and spare parts and to reduce dependence on vendors.

4.4.3 Instrumentation Documentation

Section 4.4.3 of Chapter 9 states that the plant designer will be required to supply documentation for EMS equipment. The information will include the following: function of each instrument, required indication and alarm, required control actions, range, anticipated background radiation, accuracy, response time, and failure mode. Instrument vendors will be required to supply information regarding extremes in environmental conditions as well as operation and maintenance manuals.

4.4.4 Testing and Calibration

Section 4.4.4 of Chapter 9 states that testing and calibration requirements will be derived from manufacturer's recommendations and from Regulatory Guides 1.23 and 1.97.

4.4.5 Instrumentation Ranges

Section 4.4.5 of Chapter 9 states that EMS instrument ranges will be consistent with alarm setpoints and with Regulatory Guides 1.23 and 1.97. Separate instruments with overlapping ranges will be used if the required range results in inadequate sensitivity under normal conditions.

4.5 Data Management

Section 4.5 of Chapter 9 of the Evolutionary Requirements Document states that a computer-based data management and surveillance system will be provided for input and recall of all EMS and laboratory data. The system will be capable of providing daily evaluations of radiological conditions and of tracking and plotting trends.

All EMS instrument channels and the data management system will be designed to interface with the plant data transmission and data base systems for storing and sharing information.

4.6 Conclusion

The staff concludes that the requirements of Section 4 of Chapter 9 are, to the extent described, consistent with the regulatory criteria in Regulatory Guides 1.23 and 1.97. They do not conflict with current regulatory guidelines and are acceptable. However, by themselves they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document must demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

5 SITE SECURITY SYSTEM

5.1 Scope and Functions

Section 5 of Chapter 9 of the Evolutionary Requirements Document specifies the requirements for a physical security system intended to have the capability of protecting the facility against radiological sabotage, as required by 10 CFR 73.55. To achieve this function, Section 5.1.2 states that the site security system will be capable of, but not necessarily be limited to, (1) preventing unauthorized access of persons, vehicles, and materials to vital areas or protected areas; (2) detecting attempts by unauthorized persons to gain access to or to introduce unauthorized material across protected or vital area boundaries; (3) facilitating authorized activities and conditions within protected and vital areas; and (4) providing for authorized access to and ensuring the detection of and response to unauthorized penetrations of protected or vital area boundaries.

Section 1.4.1 of Chapter 9 provides the policy statement on protection against sabotage. It identifies the reactor design features, such as reinforced-concrete external walls, internal barriers, and physically separated redundant safety systems, that will provide inherent resistance to sabotage. Protected area barriers, lighting, and intrusion detection systems will be relied on to provide the primary defense against the external threat.

In the DSER for Chapter 9, the staff identified design enhancements for sabotage protection as a confirmatory issue because it concluded that the policy statement in Section 1.4.1 of Chapter 9 needed to be amended to be consistent with Section 5. The staff has verified that EPRI has revised Section 1.4.1 of Chapter 9 to reflect the emphasis that Section 5 requires be given to sabotage vulnerabilities during the design process. Therefore, this DSER confirmatory issue is closed.

Section 5.1.3 of Chapter 9 provides the following assumptions and general design criteria for use in the design of the site security system. Section 5.2.2 requires a reactor designer to conduct a sabotage vulnerability analysis, using these criteria and assumptions, before finalizing the design.

- The insider sabotage threat is based on one knowledgeable individual without armament or explosives.
- The security detection systems cannot be disabled without detection and timely response by the security force.
- Sabotage can potentially result in an initiating event requiring actuation of safe shutdown systems, in the disabling of safe shutdown systems, in the disabling of non-safety-related systems, or any combination of these.
- In evaluating the vulnerability to insider sabotage, it is assumed that outsiders cannot succeed in penetrating the protected area.
- Equipment inside the containment is inaccessible to a saboteur during operation at power if security systems are provided to protect and control containment access.

- The continuous presence of several employees precludes acts of sabotage in the control room.

- Systems and equipment designated as vital for full-power operation will be maintained as vital during other modes of operation, except that during periods of plant shutdown, a vital area can be devitalized if approved in the physical security plan.

- Acts of sabotage are not assumed to occur concurrent with an independent single failure or other independently initiated event.

- The quality assurance program requirements of 10 CFR Part 50, Appendix B, do not apply to the security system, except at interfaces with safety systems where necessary to preclude adverse system interactions.

- Security restrictions for access to equipment and plant regions must be compatible with the access and exit needed for fire protection, with health physics access restrictions, and with local operator actions required for event mitigation. Security controls must provide for access during a loss of security system power and should not impede operator actions.

The basis for the staff's review of Section 5 of Chapter 9 includes 10 CFR 73.55; Section 13.6, Revision 2, "Physical Security," of the SRP (NUREG-0800); and NUREG-0908, "Acceptance Criteria for the Evaluation of Nuclear Power Reactor Security Plans."

In the DSER for Chapter 9, the staff identified sabotage considerations for the control room as an outstanding issue. The staff did not accept the assumption that the presence of several persons precludes acts of sabotage absent a requirement ensuring that control room operators are aware of any maintenance activities or tampering with back panels that are out of their view. In its letter of July 22, 1991, EPRI stated that Chapter 10 of the Evolutionary Requirements Document includes appropriate requirements to justify the assumption. The staff has verified that Section 3.7.7.6 of Chapter 10 includes a requirement for indication when testing that affects equipment operability is in progress and concludes that this is acceptable. Therefore, this DSER open issue is closed.

The staff will evaluate EPRI's assumption that a security area can be devitalized during unit shutdown, if approved in the physical security plan, during its review of an individual application for FDA/DC.

5.2 <u>Performance Requirements</u>

5.2.1 Protection Strategies

Section 5.2.1 of Chapter 9 of the Evolutionary Requirements Document requires that a physical security system be provided for protecting vital equipment in accordance with 10 CFR 73.55. Vital equipment requiring protection against radiological sabotage is defined in this section as (1) the reactor coolant pressure boundary out to and including a single normally closed isolation valve; (2) the spent fuel pool and associated piping, equipment, and controls whose failure could result in an offsite release in excess of 10 CFR Part 100 limits; and (3) the equipment necessary for preventing core damage. All redundant divisions of the latter are to be protected. This section also requires that the physical security system be provided with tamper-detection alarms to ensure that the security force is cognizant of unauthorized disablement of the system.

In the DSER for Chapter 9, the staff identified guidance designation of vital equipment as a confirmatory issue because EPRI had committed to modify Section 5.2.1 of Chapter 9 to reference NRC Review Guideline 17 instead of NUREG-1178 as the applicable guidance. The staff has verified that Chapter 9 of the Evolutionary Requirements Document contains this requirement. Therefore, this DSER confirmatory issue is closed.

5.2.2 Protection Methodology

Section 5.2.2 of Chapter 9 specifies that, before the plant design is completed, a sabotage vulnerability analysis will be performed and improvements found to be practical will be included in the design. The analysis will include a review of the effect on sabotage vulnerability of plant features, including (1) the arrangement of plant systems; (2) the location and design of flooding, fire, and missile barriers; and (3) the separation of redundant safety-related systems.

In the DSER for Chapter 9, the staff identified insider sabotage vulnerability analysis as a confirmatory issue because EPRI had committed to modify the Evolutionary Requirements Document to specify that the analysis will include consideration of both insider and outsider threats. In the revisions submitted by letter dated January 24, 1992, EPRI deleted specific reference to "insider and outsider" that it had previously inserted as part of its earlier commitment. The staff will review an individual application for FDA/DC to ensure that it includes vulnerability analyses that address insider tampering and also includes either the external assault threat defined in 10 CFR 73.55(a)(1)(i) or interface requirements for such analyses to be done on a site-specific basis. Therefore, this DSER confirmatory issue is closed.

5.2.3 Vital Equipment Evaluation

Section 5.2.3 of Chapter 9 specifies that a comprehensive listing and evaluation of all vital systems and equipment will be prepared for use in ensuring that all systems required to mitigate a 10 CFR Part 100 release are located within a vital area.

In the Evolutionary Requirements Document, EPRI notes that 10 CFR 73.21 requires that this information, once formulated, be controlled as unclassified sensitive safeguards information (SGI) following the procedures of 10 CFR 73.57 and NUREG-0794.

The current staff interpretation of 10 CFR 73.21 is that one of the conditions necessary before "documents or other matter" must be designated SGI in accordance with 10 CFR 73.21(b)(1)(vii) is: "The physical protection measures (other than any general regulatory requirement stated in 10 CFR 73.55) afforded the equipment or area, as described in either a physical security plant, safeguards contingency plan, or in a plant specific safeguards analysis, must also be specifically described in the documents or other matter."

5.2.4 Vital Component Layout

Section 5.2.4 of Chapter 9 specifies that the locations of vital equipment will be selected to be compatible with the requirements pertaining to physical separation, missile protection, fire protection, flooding protection, and access for maintenance. Access will require passage through at least two physical barriers (i.e., protected area boundary and vital area boundary). The security system's effect on normal and emergency operating activities will be evaluated.

In the DSER for Chapter 9, the staff identified inaccessibility of cable and piping runs connecting two protected areas as a confirmatory issue because EPRI had committed to add a requirement that cable and piping runs that connect vital equipment in two separated protected areas be inaccessible outside the protected areas. The staff has verified that Section 5.2.4 of Chapter 9 contains this requirement. Therefore, this DSER confirmatory issue is closed.

5.2.5 Physical Protection Measures

Section 5.2.5 of Chapter 9 identifies the physical features to be incorporated into the plant design for use in conjunction with the security system. These features include the following:

- Vital area walls, floors, and ceilings will be hardened to delay penetration of these areas so that the security force has enough time to respond to an intrusion attempt.
- The central alarm station, the control room, and the protected area control station will have bullet-resistant features.
- Utility port (piping, HVAC, electrical, etc.) openings in protected area boundaries and vital area boundaries will be minimized and will include provisions to ensure they do not compromise security.
- Walls and doors will be designed to accommodate security system hardware.

In the DSER for Chapter 9, the staff identified the installation of security door hardware as a confirmatory issue because EPRI had committed to add a requirement that security hardware (with the exception of the entrance card reader) be located on the vital or secure side of doors. The staff has verified that Section 5.2.5 of Chapter 9 contains this requirement and concludes that this change satisfies EPRI's commitment. Therefore, this DSER confirmatory issue is closed.

5.2.6 Strategy for Inoperable Vital Equipment

Section 5.2.6 of Chapter 9 requires a strategy to minimize the effect that an out-of-service division of vital equipment would have on the security force's compensatory measures.

5.2.7 Protected Areas and Boundaries

Section 5.2.7 of Chapter 9 requires that physical protection measures be considered in physical site planning. It cites the following examples of physical site planning related to security:

- Site support buildings such as warehouses and office buildings will be located to facilitate required searches for access to the protected area.
- Personnel, vehicle, and cargo access portals will be located to expedite the processing required for plant personnel and vehicle traffic.
- The topography of the protected area boundary will be as flat as possible, and excessive changes in direction will be avoided.
- The isolation zone dimensions will be large enough to accommodate the intrusion detection system technology selected.
- To the extent possible, bodies of water will not coincide with the protected area boundary.
- Closed circuit television, lighting, and detection equipment in the isolation zone will not interfere with observation of the isolation zone on both sides of the protected area barrier.
- Intrusion alarms will indicate intrusion attempts by zone identification at consoles in the central alarm station (CAS) and the secondary alarm station (SAS).
- The size and number of subterranean passages under the protected area boundary will be minimized.
- Security systems and equipment, including CAS and SAS, power supplies, and communications equipment, will be located within the protected area.

In the DSER for Chapter 9, the staff identified alarm assessment coverage of the interior of the intrusion detection system as a confirmatory issue because EPRI had committed to revise Section 5.2.7.1 of Chapter 9 to require unobstructed coverage of the area interior to the detection equipment, including the protected area fence, in order to ensure adequate alarm assessment. The staff has verified that EPRI's January 24, 1992, revision of Section 5.2.7.1 satisfactorily addresses this issue by the addition of guidance on the need for assessing the area of penetration. Therefore, this DSER confirmatory issue is closed.

5.2.8 Design Margins

Section 5.2.8 of Chapter 9 specifies that security facilities will be designed with features to facilitate the replacement and modification of security equipment. Such features include (1) maintenance access areas behind CAS and SAS consoles for the protected area perimeter, (2) perimeter cable trenches for security devices in the protected area perimeter, (3) trenches or raised floors for cable routing in security equipment rooms, and (4) sizing of subsystem capacities (e.g., security power supply, security computer, HVAC, and maximum number of detection and assessment zones) with margin for future expansion.

5.2.9 Training Facilities

Section 5.2.9 of Chapter 9 specifies that the location of the security training facility will be considered. Provision of an onsite training facility is encouraged.

5.2.10 Access Control

Section 5.2.10 of Chapter 9 identifies the design features for portals controlling vehicle and personnel access to vital and protected areas. Required features include (1) means for positive identification of authorized individuals requiring and allowed access to protected areas; (2) means to search for and detect firearms, incendiary devices, and explosives; (3) means to control the last access into the protected area from within a bullet-resistant structure that requires a permit/concur actuation before access is allowed; (4) means for positive identification of individuals requiring and allowed access to vital areas; (5) alarming and logging of access portals; and (6) interfacing of access control with health physics and fire protection requirements so that only one door control mechanism is required.

Section 5.2.10.2 of Chapter 9 specifies that the security access controls will accommodate possible needs for rapid access to or from vital areas under emergency conditions.

5.2.11 Communications

Section 5.2.11 of Chapter 9 specifies that a security communications system will be provided. The system will provide (1) each onsite security officer, watchman, or armed response individual with continuous two-way voice communications capability with the CAS, SAS, or personnel access portal; (2) communications capability between the CAS and SAS and local law enforcement agencies; (3) dedicated telephone communications capability between the main control room and the CAS and SAS; and (4) alarm indication of failure of or tampering with the communications system.

In the DSER for Chapter 9, the staff identified the use of hand-held radios in plant buildings as a confirmatory issue because EPRI had committed to add a requirement in Chapter 10 to ensure the capability to use hand-held wireless communications devices anywhere in the plant. The staff has verified that Section 4.6.3.6 of Chapter 10 contains this requirement. Therefore, the DSER confirmatory issue is closed.

5.2.12 Power Source

In the DSER for Chapter 9, the staff stated that Section 5.2.12 specified that the security system will be powered by a noninterruptible electric power source, with the exception, because of the size of the load, of protected area boundary lighting. The physical security plan was to include the compensatory measures to be taken if the boundary lighting was lost.

The staff also identified backup power for security lighting as a confirmatory issue because EPRI had committed to revise Section 5.2.12 of Chapter 9, to resolve an inconsistency between this section and Chapter 11, by requiring that the security equipment onsite secondary power supply be located in a vital area.

EPRI has revised the design requirements to provide for a separate, dedicated, uninterruptible backup power source located in a vital area and to include a security diesel generator, uninterruptible power supply cabinets, and batteries. The staff concludes that these revisions satisfactorily address its concerns. Therefore, this DSER confirmatory issue is closed. In a letter dated January 24, 1992, EPRI proposed a change to Section 5.2.12.3 that would allow only selected parts of security lighting to be backed up with interruptible power. Security lighting requirements are also included in Chapter 11 of the Evolutionary Requirements Document. The staff concludes that this change is compatible with existing regulatory requirements and is acceptable.

The security power supply will be alarmed at the CAS and SAS to ensure its availability.

5.2.13 Data Management

Section 5.2.13 of Chapter 9 specifies redundant on-line security central computers with "smart" interfaces on remote security equipment that will permit their interim standalone operation should communications with the central computers be interrupted.

Chapter 10 of this report provides the staff's evaluation of EPRI's requirements concerning computers, including the precautions to be taken to protect security computers with "smart" interfaces on remote security equipment against computer viruses.

5.3 Conclusion

The staff concludes that none of the requirements in Section 5 of Chapter 9 of the Evolutionary Requirements Document will prevent compliance with existing NRC security requirements and that acceptable design requirements to facilitate compliance with 10 CFR 73.55 have been specified. The staff will evaluate satisfactory compliance with these requirements during its review of an individual application for FDA/DC. This evaluation will not replace the site-specific review of security, contingency, and guard training plans required by 10 CFR 50.34 and 10 CFR Part 73.

6 DECONTAMINATION SYSTEM (FACILITIES)

Section 6 of Chapter 9 of the Evolutionary Requirements Document provides the requirements for the various decontamination systems or facilities that will be used to remove radioactive contaminants from plant equipment, protective clothing, and personnel or to reduce them. EPRI states that the functions of the various decontamination systems or facilities include the following:

- reduce area dose rates to an acceptable level for subsequent maintenance, inspection, or repair

- reduce contamination and radiation levels to permit the disposal of equipment or to facilitate the repair of equipment, consistent with as-low-as-is-reasonably-achievable guidelines

- remove as much surface activity as is required so as not to compromise subsequent plant operations

- provide facilities and supplies for personnel decontamination

Decontamination systems (including electropolishing units and degreasing units) for plant equipment will be sized to accommodate large components that may require decontamination on a regular basis. Decontamination facilities will also be available for the decontamination of small tools and instruments to permit their reuse. The plant designer will select the specific decontamination techniques that will be used at each plant. However, EPRI recommends the use of the decontamination techniques that are specified in EPRI NP-6433 and NP-2777.

Section 6.2.2 of Chapter 9 states that areas for decontaminating equipment and personnel will be provided in the primary containment, fuel handling and storage facility, auxiliary and turbine buildings, health physics facilities, plant radwaste facilities, and contaminated shops. These areas will have provisions for temporary shielding and will be provided with alarmed radiation monitors to alert personnel to unexpected radiation levels near decontamination equipment. A clean staging, decontamination, and checkout area will be provided for applying and removing protective materials used for tools and instruments that will be used in the containment during outage inspection and maintenance activities. This area will help to reduce congestion at the containment entrances and exits and will expedite worker traffic into and out of the containment. An area will also be provided for storing contaminated equipment awaiting decontamination or disposal.

Section 6.2.4 of Chapter 9 states that the plant designer must ensure that the decontamination factors and the radioactive waste generated during the decontamination processes are as low as is reasonably achievable. Procedures must be in place to ensure that systems and components are properly isolated during decontamination and are flushed to remove decontaminants following decontamination. Means will be provided to transfer chemical and radioactive wastes safely from the systems or components being decontaminated to the appropriate radwaste systems

Regulatory Guide 8.8 states that doses to personnel can be reduced by decontaminating systems or components before they are serviced. The staff concludes that the decontamination methods and facilities described in Section 6 of Chapter 9 of the Evolutionary Requirements Document are intended to facilitate decontamination of equipment, protective clothing, and personnel; comply with the guidelines in Regulatory Guide 8.8; and are, therefore, acceptable.

In addition, the specifications for the decontamination system in Section 6 of Chapter 9 of the Evolutionary Requirements Document are consistent with the criteria of SRP Sections 11, "Radioactive Waste Management," and 12, "Radiation Protection," and are, therefore, acceptable.

7 COMPRESSED AIR AND GAS SYSTEMS

7.1 Compressed Air System

Section 7 of Chapter 9 of the Evolutionary Requirements Document specifies that the compressed air system will consist of three separate and isolated subsystems: the plant service air system, the instrument air system, and the breathing air system. The plant service air system will provide a continuous supply of dry compressed air for air-operated tools, miscellaneous equipment, and various maintenance purposes. The instrument air system will provide a continuous supply of dry, oil-free, filtered compressed air to all air-operated instrumentation and valves in accordance with the guidelines in American National Standards Institute (ANSI) MC11.1-1976 (ISA-57.3), "Quality Standard for Instrument Air Systems." The breathing air system will supply clean, oil-free, low-pressure air to various locations in the auxiliary building and in the containment for protection against airborne contamination during certain maintenance, inspection, and cleaning operations. EPRI states that these systems will not be safety related, with the exception of containment penetrations, accumulators, and check valves upstream of accumulators used for air-operated safety-related valve actuators in other ALWR systems designated as safety related. The air and gas system piping between the outer containment isolation valves and the accumulators will also be safety related. EPRI states that these systems are not required to achieve safe reactor shutdown or to mitigate the consequences of an accident. Failure of the non-safety-related portions of the plant service air, instrument air, and breathing air systems will not prevent safety-related components or systems from performing their intended safety functions. The staff's evaluation of the safety-related portions (containment penetrations) of these systems is provided in Chapter 5 of this report.

Section 7.3.4 of Chapter 9 requires that ALWRs for which the Evolutionary Requirements Document is applicable have a periodic instrument air quality sampling program and that sample lines and valves be provided for obtaining air samples from air-operated safety-related plant equipment. These requirements, which are not required for the instrument air systems used in current nuclear power plants, will enhance the reliability and availability of the ALWR instrument air system.

EPRI states that the breathing air system will provide purified low-pressure breathing air for various locations within the plant for protection against airborne contamination while maintenance, inspection, and cleaning operations are being performed. Section 7.3.3 of Chapter 9 specifies that the plant breathing air quality will meet the breathing air quality standards of ANSI Z86.1. Complete isolation of different air supplies, including the breathing air supply, will be ensured by using separate, all-welded air supply headers and piping. Cross connection of different gas supply systems will be prevented by using unique air fittings and identification tags. Regulatory Guide 8.8 states that the use of respiratory protection, including the use of supplied breathing air, is acceptable when the application of engineering controls is not feasible for providing protection against airborne radioactive material. Therefore, the design features described in this section to ensure that quality breathing air is available for respiratory protection are acceptable.

The staff concludes that the design requirements in Section 7 of Chapter 9 of the Evolutionary Requirements Document for the compressed air system do not conflict with the guidance in SRP Section 9.3.1, "Compressed Air System," or Regulatory Guide 8.8. However, several incidents (e.g., the cutting off of the air supply to vital instruments because excessive moisture in the instrument air line froze, and the presence of desiccant particles in the instrument air systems that contributed to the loss of the salt water cooling system at San Onofre and the slow closure of a containment isolation valve at Rancho Seco) prompted the staff to issue Generic Letter (GL) 88-14, "Instrument Air Supply System Problems Affecting Safety-Related Equipment," dated August 8, 1988, to ensure the reliability and availability of the instrument air systems in operating plants. Therefore, in the DSER for Chapter 9, the staff concluded that it was appropriate for EPRI to incorporate the requirements of GL 88-14 into the Evolutionary Requirements Document and identified this as an open issue. Table B.1-2 of Appendix B to Chapter 1 has been revised to incorporate the requirements of GL 88-14 that are applicable to instrument line designs.

EPRI requires that the ALWR instrument air system be separated from the breathing air system and service air system. The system design criteria include

- water vapor dew point at operating pressure, 18 °F below lowest outdoor temperature
- particulates less than 1 micron

In addition, EPRI requires plant designers to evaluate the instrument air system to ensure that check valves isolate in the event of a slow pressure loss in the instrument air system and to provide for sampling capability to ensure continued operation of the check valves and accumulators.

The staff concludes that the ALWR instrument air system design has been improved to prevent moisture and particulates from causing failures of instrument air lines and that incorporation of the requirements of GL 88-14 will help to ensure the reliability of the instrument air system. Therefore, the revised design requirements for the instrument air system are acceptable and the DSER open issue is closed.

7.2 Compressed Gas System

Section 7 of Chapter 9 of the Evolutionary Requirements Document states that the function of the compressed gas system is to provide pressure-regulated supplies of various gases needed for cooling, purging, diluting, inerting, and welding. The compressed gas system will consist of the following subsystems: nitrogen, hydrogen, oxygen, carbon dioxide, argon/methane, acetylene, and argon systems. These systems will not be safety related, with the exception of containment penetrations designated as safety related. Failure of the compressed gas system will not prevent safety-related components or systems from performing their intended safety functions. The staff's evaluation of the safety-related portions (containment penetrations) of these systems is provided in Chapter 5 of this report.

The staff concludes that the design requirements in Section 7 of Chapter 9 for the compressed gas system do not conflict with NRC regulatory guidelines and are, therefore, acceptable.

8 HEATING, VENTILATING, AND AIR CONDITIONING SYSTEM

8.1 Scope and Functions

Section 8.1 of Chapter 9 of the Evolutionary Requirements Document states that the functions of the heating, ventilating, and air conditioning (HVAC) system are the following:

- maintain work environments within the comfort levels required for operating and maintenance personnel
- ensure that the proper environment is maintained for equipment and structures
- ensure that HVAC flow paths are designed so that flow is not directed from a volume with a higher potential for airborne radioactivity to one with a lower potential
- provide HVAC designs that segregate plant areas in response to signals from the fire protection system
- ensure that the HVAC design meets security system requirements for bullet resistance and personnel barriers
- maintain appropriate relative pressure within a building or volume to ensure controlled leakage of potentially radioactive effluents
- inhibit the spread of contamination by providing appropriate HVAC filtration systems to remove contamination
- ensure that ventilation system exhausts to the environment are within the limits specified in 10 CFR Part 20 for normal conditions and 10 CFR Part 100 for accident conditions
- ensure that the design objectives of 10 CFR Part 50, Appendix I, can be met for normal operation and anticipated operational occurrences
- prevent migration of smoke, hot gases, and fire suppressants into other fire areas to the extent that safe shutdown capabilities, including operator actions, could be adversely affected

8.2 Common Performance Requirements

Section 8.2 of Chapter 9 of the Evolutionary Requirements Document establishes the key requirements for the design of safety-related and non-safety-related HVAC systems applicable to both BWRs and PWRs.

8.2.1 General Requirements

Section 8.2.1 of Chapter 9 establishes the general requirements for both safety-related and non-safety-related HVAC systems.

Safety- and Non-Safety-Related HVAC Systems

The following is a summary of the key requirements for both safety- and non-safety-related HVAC systems provided in Section 8.2.1.1 of Chapter 9:

- HVAC systems will provide a suitable environment in accordance with General Design Criteria (GDC) 4 and 19 of 10 CFR Part 50, Appendix A, and the recommendations of the American Society of Heating, Refrigerating, and Air Conditioning Engineers to ensure the safety and comfort of plant personnel and the operability of plant equipment during normal operating and postulated design-basis-accident conditions.

- HVAC systems of areas or buildings that may contain radioactivity will be designed in accordance with GDC 60, 61, and 64; 10 CFR Part 20; 10 CFR Part 50; 10 CFR Part 73; 10 CFR Part 100; Regulatory Guides 1.52 ("Design, Testing, and Maintenance Criteria for Postaccident Engineered - Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants") and 1.140 ("Design, Testing, and Maintenance Criteria for Normal Ventilation Exhaust System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants"); American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1, NQA-2, N509, N510, and AG-1; and ANSI/American Nuclear Society (ANS) 59.2 to

  - maintain negative ambient pressures with respect to the atmosphere and contiguous areas

  - filter exhaust air to reduce controlled radioactivity releases to the environment

  - provide continuous exhaust air monitoring (with high-level alarms in the control room) of each potentially contaminated discharge point

  - provide internal cleanup and/or an outside air supply for maintaining the levels of maximum permissible concentrations within as-low-as-is-reasonably achievable (ALARA) guidelines

  - provide means to locate and isolate the ventilation air of the area containing a radioactive leak

- HVAC systems will be designed so that air flow is not directed from volumes with higher potential for airborne radioactivity to volumes with lower potential.

- Penetration openings for ventilation systems in fire-rated barriers will be protected by fire dampers having a rating equivalent to that required for the barrier.

- HVAC duct penetrations through security boundaries will be equipped with an appropriate barrier.

- HVAC systems will be provided with sufficient instrumentation and controls to ensure safe, efficient, and reliable operation.

- Instruments and instrument taps of proper size, sufficient quantity, and proper location will be provided to allow initial and periodic testing of components and equipment to demonstrate their operation within performance limits.

- All nuclear air treatment filtration systems will be designed, fabricated, installed, and tested in accordance with Regulatory Guide 1.52 (for safety-related systems), Regulatory Guide 1.140 (for non-safety-related systems), and ANSI/ASME N509 and N510.

- The system heat removal capacity will include a margin of 15 percent of the total heat load and 15 percent of system pressure loss.

Safety-Related HVAC Systems

The following is a summary of the key requirements for safety-related HVAC systems only, as provided in Section 8.2.1.2 of Chapter 9:

- HVAC systems will be designed in accordance with GDC 2, 4, and 17 to withstand a safe shutdown earthquake and will be capable of accomplishing their intended functions assuming a single failure of an active component and a loss of offsite power.

- The HVAC equipment divisions will be designed in accordance with GDC 4 and ANSI/ANS 58.9 so that they are separated from each other by physical barriers.

- All outside air intake and exhaust openings will be designed in accordance with GDC 2 and Regulatory Guides 1.117, "Tornado Design Classification," and 1.76, "Design Basis Tornado for Nuclear Power Plants," and will be protected against tornado effects consistent with the requirements of Section 4 of Chapter 1 of the Evolutionary Requirements Document.

- HVAC systems will be designed in accordance with GDC 35, Regulatory Guide 1.52, and SRP Sections 6.5.1 ("ESF Atmosphere Cleanup Systems") and 9.4.5 ("Engineered Safety Feature Ventilation System"), and will be placed in operation automatically on receipt of a safety actuation signal or will be interlocked to start with associated safety equipment.

- Motors, fans, dampers, and other components of HVAC systems will be designed in accordance with GDC 4 and 10 CFR 50.49 to operate in environments associated with the normal and accident conditions to which they will be exposed.

- Provisions will be incorporated in the HVAC system design to allow the monitoring of proper system operation in the control room.

- All HVAC units and components and supports and hangers will be designed, constructed, and installed in accordance with ANSI/ASME AG-1 and N509.

- HVAC systems will be designed to permit appropriate inservice inspections and functional testing in accordance with ANSI/ASME N510.

- HVAC systems will have the capability to isolate nonessential system portions from essential components by redundant, automatically actuated dampers. Dampers will be Safety Class 2, seismic Category 1. Isolation components of containment penetrations will be Safety Class 2, seismic Category 1.

- HVAC system configurations will be compatible with fire zone boundaries.

HVAC Penetrations of Fire Barriers

Section 8.2.1.1.4 of Chapter 9 states that penetration openings for ventilation systems in fire-rated barriers will be protected by fire dampers having a rating equivalent to that required for the barriers. In the DSER for Chapter 9, the staff identified a confirmatory issue concerning the use of duct wrap or other material having a fire rating equivalent to that of the barrier in places where a fire damper is not suitable. EPRI has deleted all reference to duct wrap as a substitute for fire dampers. The staff concludes that the requirements of Section 8.2.1 of Chapter 9 of the Evolutionary Requirements Document are consistent with the enhanced fire protection criteria discussed by the staff in Section 3 of this chapter and are, therefore, acceptable. Therefore, the DSER confirmatory issue is closed.

Operability of Safety-Related Systems in Areas With Shared HVAC Systems

In a letter dated June 8, 1989, the staff indicated its concern about the continued operability of safety-related equipment in areas shared by HVAC systems in which air flow has been interrupted because of the closure of automatic fire dampers.

In its October 19, 1989, response, EPRI stated that specific details to address this concern were beyond the scope of the Evolutionary Requirements Document. However, EPRI committed to provide a requirement that the design of fire area boundaries and individual HVAC system configurations be compatible with the capability for redundant safe shutdown. The staff identified this as a confirmatory issue in the DSER for Chapter 9. The staff has verified that EPRI has added Section 8.2.1.2.9 of Chapter 9, which requires that HVAC system configuration be compatible with fire zone boundaries. Therefore, this DSER confirmatory issue is closed. In addition, the staff will evaluate the details of the detailed design of the HVAC system during its review of an individual application for FDA/DC.

Design of Air Filtration Systems

Section 8.2.1.1.8 of Chapter 9 requires that all nuclear air treatment filters will be designed, fabricated, installed, and tested in accordance with Regulatory Guide 1.52 (for safety-related systems), Regulatory Guide 1.140 (for non-safety-related systems), ANSI/ASME N509 and ANSI/ASME N510. In the DSER for Chapter 9, the staff concluded that this requirement should be imposed on not only the filters, but also the filtration systems, and recommended that the requirement be revised to read "all nuclear air treatment filtration systems shall be designed....," instead of "all nuclear air treatment filters shall be designed...." This was identified as an open issue in the DSER.

EPRI has revised Section 8.2.1.1.8 of Chapter 9 to require application of the regulatory guides and the referenced standards to all nuclear air treatment filtration systems, not just the filters. The staff concludes that these revisions are acceptable. Therefore, this DSER open issue is closed.

Structural Design of HVAC Systems

Section 8.2.1.2.1 of Chapter 9 states that all safety-related HVAC systems in the ALWR will be designed to withstand a safe shutdown earthquake and will be capable of accomplishing their intended functions assuming a single failure of an active component and a loss of offsite power. Section 8.2.1.2.7 of Chapter 9 specifies that the HVAC components and supports will be designed, constructed, and installed in accordance with ANSI/ASME AG-1 and N509. Because portions of ANSI/ASME AG-1-1988, including rules for the design of HVAC ductwork, are still being prepared, the staff has not yet fully endorsed this standard.

In the interim, the staff concludes that Article AA-4000, "Structural Design," in the 1988 revision of ANSI/ASME AG-1 provides minimum design requirements for the structural design of HVAC equipment and supports that the staff deems are acceptable. In Revision 2 of Regulatory Guide 1.52 (March 1978), the staff recommends that ductwork be designed, constructed, and tested in accordance with Section 5.10 of ANSI/ASME N509.

In the DSER for Chapter 9, the staff stated that EPRI should revise the reference to ANSI/ASME AG-1 in the Evolutionary Requirements Document to include a commitment to the 1988 revision of this standard and identified this as an open issue. EPRI has revised Table 1.4-2 in Chapter 1 to include a reference to ANSI/ASME AG-1-1988.

The staff concludes that the design criteria in Chapter 9, Section 8.2.1.2, supplemented by applicable criteria in Chapter 1, Section 4, and by the commitment to ANSI/ASME AG-1-1988 in Chapter 1, Table 1.4-2 of the Evolutionary Requirements Document provide an acceptable minimum design basis for ensuring that HVAC components and supports will withstand the most adverse combination of loading events without loss of structural integrity. Therefore, this DSER open issue is closed.

However, the staff will continue to review the acceptability of the detailed HVAC design criteria that are being developed for ANSI/ASME AG-1. The staff's approval of the above interim HVAC design criteria for ALWRs does not preclude the application or use of a final NRC-approved version of this standard. For standard ALWR plant designs, the staff will require that each applicant submit its detailed HVAC design criteria and design acceptance criteria to be used for safety-related HVAC systems for staff approval during the staff's review of an individual application for FDA/DC.

Use of Radiation-Damage-Resistant Materials

As discussed by the staff in Section 2.2.4 of this chapter, the use of radiation-damage-resistant materials in high-radiation areas will reduce the need for frequent replacement and thereby will reduce personnel radiation exposure. EPRI had committed to provide guidance for this issue in revisions of the Evolutionary Requirements Document and this was identified as a confirmatory issue in Sections 2.2.4 and 8.2.1 of the staff's DSER for Chapter 9.

The staff has verified that EPRI has made acceptable revisions to the Evolutionary Requirements Document to address this issue. Therefore, this DSER confirmatory issue is closed.

Use of Charcoal Filters in HVAC Systems

The original version of the Evolutionary Requirements Document stated that charcoal filtration was unnecessary because activated charcoal filters in BWR standby gas treatment systems and other PWR ventilation systems were required solely for the removal of elemental iodine and the amount of elemental iodine expected to be released in an accident was small. Therefore, the Evolutionary Requirements Document did not require charcoal filters in any of the fission product filtration systems.

In the DSER for Chapter 9, the staff concluded that the complete removal of charcoal filters in air filtration systems, as proposed by EPRI, was not justified and, therefore, was not acceptable. The staff noted that the requirements of Section 8.2.1 were for normal (not engineered safety features) ventilation exhaust system air filtration and absorption units.

EPRI has revised Section 8.2.1.1.22 of Chapter 9 to require that the plant designer perform analyses and evaluations to determine whether charcoal filters are needed for operational consideration in accordance with the requirements of 10 CFR Part 20 and 10 CFR Part 50, Appendix I, and evaluations for in-plant ALARA levels in accordance with Regulatory Guide 8.8. Section 8.2.1.1.22 further specifies that HVAC systems requiring charcoal filters will be provided with non-safety-related charcoal filters designed to remove activity resulting from normal and off-normal operation, in accordance with ANSI/ASME N509-1989 and Regulatory Guide 1.140. This meets the guidance in SRP Section 11.3, "Gaseous Waste Management Systems," and is acceptable. Therefore, this DSER open issue is closed.

EPRI indicates that the HVAC system will be designed to minimize the potential exposure of personnel to radioactivity from airborne contamination. To minimize time spent by personnel in radiation areas and to facilitate decontamination, the Evolutionary Requirements Document specifies that suitable facilities will be located to support maintenance and repair work performed in high-radiation areas and to support decontamination activities. These features to minimize personnel exposure and to prevent the spread of contamination comply with the guidelines of Regulatory Guide 8.8 and are acceptable.

In addition, the general design requirements in Section 8.2.1 of Chapter 9 for safety-related and non-safety-related HVAC systems do not conflict with the guidance in SRP Sections 9.4.1, "Control Room Area Ventilation System"; 9.4.2, "Spent Fuel Pool Area Ventilation System"; 9.4.3, "Auxiliary and Radwaste Area Ventilation System"; 9.4.4, "Turbine Area Ventilation System"; and 9.4.5, "Engineered Safety Feature Ventilation System"; and are, therefore, acceptable.

However, the requirements by themselves do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

8.2.2 Control Complex HVAC Systems

Section 8.2.2 of Chapter 9 states that the control building will include the control room envelope, the computer room, essential switchgear rooms, battery rooms, and HVAC equipment rooms. The staff's evaluation of the HVAC system for the control room envelope is provided below. The staff's evaluation of the HVAC systems for the other areas of the control building is provided in Section 8.2.6 of this chapter.

Control Room Envelope HVAC System

The control room envelope HVAC system will service the control room and the facilities provided for the convenience of the operators (i.e., shift supervisor's office, operator washroom, kitchen, etc.). Section 8.2.2.1 of Chapter 9 states that the system will consist of two redundant, full-capacity equipment trains, each containing an air handling unit (AHU), a smoke purge fan, an emergency filter unit (EFU), associated power supply, ductwork, dampers, and controls. Each AHU will consist of a prefilter, a high-efficiency particulate filter, a heating and cooling coil, and a supply fan. The cooling coils will be served by the essential chilled water system. Each EFU will consist of a prefilter, a high-efficiency particulate air filter, and a supply fan.

EPRI states that all essential components will be designed as Safety Class 3, seismic Category I, and will be powered from Class 1E emergency power sources. All essential components will be physically separated and protected from internally generated missiles and from the effects of pipe breaks. All non-safety-related equipment will be designed not to generate any missiles. During normal operation, a small portion of outside air will be mixed with return air from the control room, filtered, conditioned, and returned to the control room so as to continuously maintain a slight positive pressure in the control room. Section 8.2.2.1 of Chapter 9 states that the control room envelope atmosphere will normally be maintained at a temperature ranging from 73 °F to 78 °F, with a 1-hour maximum temperature of 85 °F, and at a maximum relative humidity ranging from 25 to 60 percent during all operating modes. Section 8.2.2.1.9 of Chapter 9 states that redundant detectors (radiation; toxic gas, as defined in Regulatory Guide 1.78, "Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release"; and smoke) will be provided in the outside air intake structures to isolate the control room envelope HVAC system on receipt of a high-level detection signal. The outside air dampers will be in the closed position before the detected contaminated air reaches the isolation damper's downstream side. The isolation dampers will be of leaktight construction with fail/close-type operators. When airborne radioactivity is high, outside makeup air will be supplied through the EFUs. When high levels of toxic gas or outside smoke are detected, the control room envelope HVAC system will operate in the recirculating mode without a supply of outside makeup air. Section 8.2.2.1.9 of Chapter 9 states that the EFU will start automatically on receipt of a high-level airborne contamination signal and/or a safety actuation signal. In addition, the control room envelope HVAC system will be capable of removing smoke from the control room after a fire; the quantity of outside air will be increased to 100 percent of the system's supply air flow rate. However, EPRI states that the smoke purge subsystem will have no safety-related function.

Control Room Occupancy

At one time, Section 8.2.2.1 of Chapter 9 of the Evolutionary Requirements Document specified the provisions for continuous occupancy of the control room envelope for a minimum of 5 days following a design-basis accident. In the DSER for Chapter 9, the staff stated that this requirement did not satisfy the guidance in SRP Section 6.4, "Control Room Habitability System," which, in part, states that the air inside a 100,000-ft^3 control room would support five persons for a least 6 days.

EPRI has revised Section 8.2.2.1.1 of Chapter 9 to require that among other things, the main control room HVAC system be designed for a prolonged continuous occupancy of a minimum of 6 days following a design-basis accident. This is in accordance with the guidance in SRP Section 6.4 and is acceptable. Therefore, the DSER open issue is closed.

Bullet Resistance of Control Room

In the DSER for Chapter 9, the staff identified bullet resistance of the control room as a confirmatory issue because EPRI had committed to modify the Evolutionary Requirements Document to include in Section 8.2.2 of Chapter 9 the requirement of 10 CFR 73.55(c)(6) that the control room be bullet resistant. The staff has verified that Section 8.2.2.1.13 of Chapter 9 of the Evolutionary Requirements Document contains this requirement. Therefore, this DSER confirmatory issue is closed.

Conclusion

The staff concludes that the design requirements in Section 8.2.2.1 of Chapter 9 for the control room envelope HVAC system are consistent with the guidance in SRP Sections 6.4 and 9.4.1 and are, therefore, acceptable. However, the requirements by themselves do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

8.2.3 Onsite Standby AC Power Supply Facility

Diesel Generator Building Ventilation System

Section 8.2.3.1 of Chapter 9 of the Evolutionary Requirements Document establishes the requirements for the safety onsite power supply facility, which will consist of a normal and emergency ventilation subsystem for each emergency diesel generator subcompartment. The key requirements include the following:

- The normal ventilation subsystem will be designed as a non-safety-related and non-seismic system.

- The normal ventilation subsystem will consist of a manually started, 100-percent-capacity fan, fresh air intake and modulated recirculating air damper, associated ductwork, and unit heaters.

- Each emergency diesel generator compartment will be desi ed with a separate exhaust system or vent piping for the combustit vapor from the fuel oil day tank.

- The normal ventilation subsystem will trip during testing or emergency actuation of the associated diesel genera or and will not adversely affect the operation of the emergency ventilation subsystem.

- The emergency ventilation subsystem will be designed as a Safety Class 3 and seismic Category I system with a Class 1E power supply.

- The emergency ventilation subsystem will be designed to maintain the room temperature in the range given in Section 8.2.1.1.1 of Chapter 9 when the emergency diesel generator is operating.

- The emergency ventilation subsystem will consist of two 100-percent-capacity fans, outside air and modulating return air dampers, cooling coils supplied by essential chilled water, and associated ductwork.

- The emergency ventilation subsystem fan will be started automatically whenever the emergency diesel generator is started. The fan will stop automatically on low temperature. The system will trip and isolate on fire detection. Provisions will be made to remove smoke after a fire. Also, the fan will be equipped with a manual start for testing and maintenance.

- The emergency ventilation subsystem will be controlled from the main control room.

The staff concludes that the design requirements in Section 8.2.3.1 of Chapter 9 for the diesel generator building ventilation system do not conflict with the guidance in SRP Section 9.4.5 and are, therefore, acceptable. However, the requirements by themselves do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

8.2.4 Security Building

Section 8.2.18 of Chapter 9 includes criteria for the design of the security building and central alarm station (CAS) HVAC systems that are intended to be compatible with security needs and requirements.

In the DSER for Chapter 9, the staff identified resistance to penetration of an unalarmed grating as a confirmatory issue because EPRI had committed, in its letter of August 18, 1989, to add to Section 8.2.1.1.4 of Chapter 9 a general requirement that all unalarmed man-sized HVAC penetrations of vital area barriers not lessen the intruder penetration resista of other unalarmed portions of the vital area barrier. This change was to extend the requirement of Section 8.2.18.4 that security building HVAC penetrations be designed to "not lessen the intruder penetration resistance of the barrier" to other vital area penetrations. This change has not yet been made. Nevertheless, the staff concludes that the requirements in Section 5 of Chapter 9 pertaining to HVAC penetrations are compatible with generally accepted practices. Therefore, this DSER confirmatory issue is closed.

8.2.5 Fuel Handling/Spent Fuel Pool Area Heating and Ventilating System

Sections 8.3.3.1.5 and 8.4.4 of Chapter 9 establish the requirements for the design of the fuel handling/spent fuel pool area heating and ventilating system. The functions of the system include the following:

- maintain the air temperature and humidity in the fuel handling area within an acceptable range so that plant personnel can perform their required tasks and undue environmentally induced degradation of equipment and structures is avoided

- maintain negative air pressure in the fuel handling area to preclude uncontrolled release of airborne radioactivity to the environment under normal operating conditions and in the event of a fuel handling accident

- limit the airborne radioactivity level in the fuel handling area to acceptable levels

For BWRs, on receipt of an engineered safety feature signal or a high-radiation signal at the refueling floor, EPRI states that the system will change the operating mode as follows:

- trip all running ventilation fans and prevent redundant fans from starting or operating

- close the normally open isolation dampers for isolation of the secondary containment

- start the standby gas treatment system (the staff's evaluation of the standby gas treatment system is provided in Section 8.3.4 of this chapter)

For PWRs, Section 8.4.4 of the Evolutionary Requirements Document states that the fuel facility ventilation system will be designed as a "once-through" system consisting of an exhaust and a supply subsystem. The key requirements include the following:

- The exhaust subsystem will be designed as a Safety Class 3, seismic Category I system supplied by Class 1E power during loss of offsite power and will be provided with two 100-percent-capacity divisions, each consisting of a prefilter, a high-efficiency particulate air filter, an exhaust fan, a booster fan, and associated ductwork, controls, and instrumentation. The Evolutionary Requirements Document does not require the provision of charcoal filters for the fuel facility ventilation system. The staff's evaluation of the elimination of charcoal filters from any emergency filter unit is provided in Section 8.2.1 of this chapter and in Chapter 5.

- The exhaust subsystem will be capable of automatic transfer from its normal (filter) bypass operating mode to an emergency filtration mode on detection of high radiation in the exhaust duct (i.e., fuel handling accident).

- The exhaust subsystem will be controlled from the main control room. A local panel will also be provided with fan status lights and alarms.

- The supply subsystem will be designed as a non-safety-related, non-seismic subsystem supplied by non-Class 1E auxiliary power and will be functional during normal plant operation only.

EPRI indicates that following a fuel handling accident, only a small amount of air will be exhausted from the fuel facility in order to maintain negative air pressure within the fuel facility to preclude uncontrolled releases of airborne radioactivity to the environment. The amount of makeup air required can be drawn in through some predetermined openings. Therefore, the supply subsystem will not be needed and will not be designed as safety related. Because of the flexibility in system design, the staff will review the detailed system design and operation and facility layout during its review of an individual application for FDA/DC to determine the need for a safety-grade supply system.

The staff concludes that the design requirements in Chapter 9 for the fuel handling/spent fuel pool area heating and ventilating system do not conflict with the guidance in SRP Section 9.4.2 and are, therefore, acceptable.

8.2.6 HVAC Systems for Miscellaneous Areas

In various sections of Chapter 9 of the Evolutionary Requirements Document, EPRI establishes specific requirements for the design of the HVAC systems for various miscellaneous areas (e.g., essential switchgear rooms, battery rooms, and service water pump house; computer room; safety-related HVAC equipment room; combustion turbine building; radwaste facility; turbine building; radiological access control building; hot machine shop; clean shops; technical support center). Section 8.2.2.4.1 of Chapter 9 provides the design requirements for the hydrogen concentration (and the measurement method) allowable in the essential battery rooms. In its August 18, 1989, response to the staff's request for additional information dated March 22, 1989, EPRI responded that the 2-percent concentration was intended to be a HVAC design requirement and not an instrumentation requirement and was in accordance with SRP Section 9.4.5 and Institute of Electrical and Electronics Engineers (IEEE) 484. Since the response does not preclude HVAC instrumentation, it is acceptable.

The staff concludes that the design requirements in Chapter 9 pertaining to the HVAC systems for these miscellaneous areas do not conflict with the guidance of SRP Sections 9.4.3, 9.4.4, and 9.4.5. However, there are insufficient details (i.e., design layout, system performance, etc.) for the staff to determine if these HVAC systems will be properly designed. Therefore, the staff will review these HVAC systems against the above-cited SRP sections during its review of an individual application for FDA/DC. In addition, the staff will evaluate the need for charcoal filters for these systems on the basis of 10 CFR Part 50, Appendix I. The staff discusses this matter further in Section 8.2.1 of this chapter and in Chapter 5.

8.3 Performance Requirements and Interfaces for BWRs

8.3.1 Introduction

Section 8.3 of Chapter 9 of the Evolutionary Requirements Document establishes the requirements for HVAC systems that are applicable to BWR designs.

8.3.2 BWR Reactor Containment Ventilation Subsystem

Section 8.3.2 of Chapter 9 establishes the requirements for the design of the BWR reactor containment ventilation subsystem. The key requirements include the following:

- The subsystem will be designed as a non-safety-related, non-seismic system powered from the permanent non-safety-related distribution system.

- During normal operation, the subsystem will maintain temperatures in various spaces such as drywell areas, control rod drive area, etc., in accordance with ANSI/ANS 56.7 and manufacturer's recommendations.

- During cold shutdown or refueling, the subsystem will provide filtered heated or cooled outside air for ventilating or purging the containment to maintain ambient temperatures within the range given in Section 8.2.1.1.1 of Chapter 9.

- The subsystem will consist of properly located fan coil units provided with adequate redundancy, i.e., the system will be fully operational with one fan coil unit out of service.

- Fan coil units that are required to operate during loss of offsite power will be powered from the permanent non-safety distribution system on loss of offsite power.

The staff concludes that the design requirements in Section 8.3.2 of Chapter 9 for the BWR reactor containment ventilation subsystem do not conflict with the guidance in SRP Sections 9.4.3 and 9.4.5 and are, therefore, acceptable. However, the requirements by themselves do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

8.3.3 BWR Reactor Building Ventilation System

Section 8.3.3 of Chapter 9 establishes the requirements for the design of the BWR reactor building ventilation system. The key requirements include the following:

- The system will be designed as a non-safety-related, non-seismic system equipped with safety-related seismically qualified redundant isolation dampers. The system will be powered from the permanent non-safety power distribution system and will operate during normal plant conditions only.

- The system will be designed to maintain the general area ambient temperatures within the ranges given in Section 8.2.1.1.1 of Chapter 9; to maintain the ambient pressure at a minimum negative pressure of approximately 0.25-inch water gauge with respect to the atmospheric pressure in all adjacent spaces; to provide ventilation, cooling, and heating to all equipment in the reactor building, including the engineered safety feature (ESF) compartments, during normal plant operation, and to provide filtered heated or cooled outside air to maintain the maximum permissible concentration levels in the cubicles within ALARA guidelines.

The staff concludes that the design requirements in Section 8.3.3 of Chapter 9 for the BWR reactor building ventilation system do not conflict with the guidance in SRP Sections 9.4.3 and 9.4.5 and, therefore, are acceptable. However, the requirements by themselves do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

8.3.4 BWR Standby Gas Treatment System

Section 8.3.4 of Chapter 9 establishes the requirements for the design of the standby gas treatment system (SGTS). The SGTS will be required to perform the following safety-related functions:

- Exhaust the required quantity of reactor building air to maintain a negative ambient pressure of at least 0.25-inch water gauge during accident conditions. This exhaust flow will be initiated by an ESF or fuel handling accident signal.

- Filter the exhausted air before it is discharged to limit the offsite dose to that specified in 10 CFR Part 100.

The key requirements for the design of the SGTS are the following:

- The system will consist of two 100-percent-capacity divisions, each provided with a bank of prefilters, a high-efficiency particulate air filter bank, an exhaust fan equipped with automatic volume control, instruments, and controls. The divisions will share common ductwork.

- The system control will be designed for automatic initiation on receipt of an ESF or fuel handling accident signal or manual start from the main control room.

  The system will be controlled from a main control room panel.

In its response dated August 18, 1989, to the staff's March 22, 1989, request for additional information, EPRI stated that the SGTS design will be consistent with the guidelines of Branch Technical Position CSB 6-4, "Containment Purging During Normal Plant Operation" (SRP Section 6.2.4, "Containment Isolation System"). However, the Evolutionary Requirements Document does not require the provision of charcoal filters for the SGTS. The staff's evaluation of the elimination of charcoal filters from any ESF filtration unit is provided in Section 8.2.1 of this chapter and in Chapter 5.

Pending the resolution of the requirement for charcoal filters, the staff concludes that the design requirements in Section 8.3.4 of Chapter 9 for the SGTS do not conflict with the guidance in SRP Section 9.4.5 and are, therefore, acceptable. However, the requirements by themselves do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

8.4 Performance Requirements and Interfaces for PWRs

8.4.1 Introduction

Section 8.4 of Chapter 9 of the Evolutionary Requirements Document establishes the requirements for HVAC systems that are applicable to PWR designs.

8.4.2 PWR Containment Cooling and Ventilation System

The PWR containment cooling and ventilation system will consist of five subsystems that will maintain environmental conditions within the containment during normal operating conditions, extended shutdowns, and refueling outages. These subsystems, which will not be required to perform any safety-related function, are the fan cooler subsystem, the control rod drive mechanism ventilation subsystem, the primary containment purge subsystem, the containment cleanup subsystem, and the reactor cavity cooling subsystem.

Section 8.4.2 of Chapter 9 establishes the requirements for the design of these subsystems. The key requirements for each of these subsystems are the following:

Fan Cooler Subsystem

- The subsystem will be designed as a non-safety-related and seismic Class II/I installation that will maintain area temperatures below 120 °F.
- The subsystem will consist of properly located fan cooler units provided with adequate redundancy; that is, the subsystem will be fully operational with one fan coil unit out of service.
- The fan coolers will be manually started from the main control room. On failure of the operating unit, the standby unit will start automatically and an alarm will be actuated on the annunciator panel.
- System operation will be monitored in the main control room by fan cooler discharge air and water temperature indicators and high-temperature alarms.
- Fan coolers that are required to operate during loss of offsite power will be powered from the standby non-safety-related power source (combustion turbine) on loss of offsite power.

Control Rod Drive Mechanism (CRDM) Ventilation Subsystem

- The subsystem will be designed as a non-safety-related system powered from the permanent non-safety power distribution system. It will be designed to remain operational during the operating basis earthquake.
- The subsystem will be designed to establish air flow through the reactor head cooling shroud to maintain the CRDM temperature within the operating limits (determined by the reactor supplier) and to exhaust the air, after absorbing the heat, in the vertical direction.
- The subsystem will consist of operating and standby fans in accordance with the requirements of the reactor supplier.
- The subsystem will be controlled manually and monitored by status lights and motor trip alarms on the main control room panel.
- The system will be powered from the permanent non-safety distribution system (combustion turbine) on loss of offsite power.

Primary Containment Purge Subsystem

Section 8.4.2.5 of Chapter 9 states that the primary containment purge subsystem will be designed as a non-safety-related system and will be powered by the non-Class 1E electrical system with the exception of containment penetration isolation components that are designated as Safety Class 2, seismic Category I. The ductwork inside the containment will be designed to seismic Category II/I criteria. The system will consist of high-volume and low-volume purge subsystems.

(1) High-Volume Purge Subsystem

- The high-volume normal purge subsystem will be designed to supply 100-percent filtered, tempered (heated or cooled) outside air to maintain containment temperatures within the range given in Section 8.2.1.1.1 of Chapter 9 before and during personnel entry for cold shutdown or refueling operations and to exhaust the same quantity of air through the exhaust filter system.
- The supply subsystem will consist of a prefilter bank, a high-efficiency filter bank, electric heating coil, cooling coil supplied by nonessential chilled water, and two 50-percent-capacity supply fans.
- The exhaust subsystem will consist of a prefilter bank, a high-efficiency particulate air (HEPA) filter, and two 50-percent-capacity exhaust fans.
- The subsystem will be manually controlled from the main control room. A local panel will also be provided with fan status indication lights and alarms actuated by high filter resistances.

- The containment isolation valves will be designed to withstand the loss-of-coolant accident (LOCA), integrated leak rate test pressures, and the high-pressure and humidity conditions generated by a main steam or feedwater pipe rupture, and to remain leaktight.

- A containment isolation signal will trip the supply and exhaust fans.

(2) Low-Volume Purge Subsystem

- The low-volume purge subsystem will be designed to supply 100-percent filtered air to the containment and in-core instrument room.

- The supply subsystem will consist of a heating coil, a prefilter bank, a high-efficiency filter bank, and two 50-percent-capacity supply fans.

- The exhaust subsystem will consist of a prefilter bank, a HEPA filter, and two 50-percent-capacity exhaust fans.

- The subsystem will be manually controlled from the main control room. A local panel will also be provided with fan status indication lights and alarms actuated by high filter resistances.

- A containment isolation signal will trip the supply and exhaust fans.

In its August 18, 1989, response to the staff's request for additional information, EPRI stated that the design of the primary containment purge subsystem will be consistent with the guidelines of Branch Technical Position (BTP) CSB 6-4, "Containment Purging During Normal Plant Operation" (SRP Section 6.2.4). However, the Evolutionary Requirements Document does not require the provision of charcoal filters for the containment purge subsystem. Should a LOCA occur during containment purging when the reactor is at power and before the purge subsystem is isolated, fission products may be released to the environment. The staff's evaluation of the elimination of charcoal filters is provided in Section 8.2.1 of this chapter and in Chapter 5. In addition, the staff will review the detailed system design operation and layout during its review of an individual application for FDA/DC to ensure that the guidelines of BTP CSB 6-4 have been satisfied.

<u>Containment Cleanup Subsystem</u>

- The plant designer will perform an analysis of anticipated containment airborne activity levels, estimated extent of personnel entries during normal plant operation, and radiation protection (ALARA) measures. This analysis will result in the establishment of the functional requirements for the containment cleanup and low-volume purge subsystems.

- The containment cleanup subsystem will be designed as a non-safety-related, non-seismic system powered from the permanent non-safety distribution system.

- The subsystem will be designed to provide air circulation and filtration to reduce the concentrations of airborne radioactivity for safe access during normal plant operation or after reactor shutdown. The system will operate on an as-required basis for a predetermined number of hours.

Reactor Cavity Cooling Subsystem

- The reactor cavity/ex-core instrumentation, reactor support, and in-core instrumentation room ventilation subsystem will be designed as a non-safety-related and non-seismic system for operation during normal plant operation and loss of offsite power.

- The reactor cavity cooling subsystem will be designed to maintain temperatures within the following specified limits:

  - Reactor cavity average concrete temperature will be 150 °F with a maximum local area temperature of 200 °F.

  - Reactor support area temperature will be 135 °F with a maximum concrete temperature of 180 °F.

  - In-core instrumentation room temperature will not exceed 120 °F.

- The subsystem will be provided with two 100-percent-capacity divisions, each consisting of a cooling coil supplied by nonessential chilled water, a supply fan, dampers, controls, and associated instrumentation.

- The subsystem will be powered from the permanent non-safety power distribution system on loss of offsite power.

Conclusion

With the exceptions noted above, the staff concludes that the design requirements in Section 8.4.2 of Chapter 9 for the PWR containment cooling and ventilation system do not conflict with NRC regulatory guidelines and are, therefore, acceptable. The staff will review the need for charcoal filters for the PWR containment cooling and ventilation system on the basis of 10 CFR Part 50, Appendix I, during its review of an individual application for FDA/DC.

8.4.3 Annulus Building Ventilation System

Section 8.4.3 of Chapter 9 originally established requirements for the design of the annulus building ventilation system, if it is needed. However, EPRI removed these requirements in Revision 3 of the Evolutionary Requirements Document. Because the ALWR design is for a large, dry, free-standing steel containment (not a dual containment with the annulus maintained at a negative pressure), and in keeping with EPRI's philosophy of eliminating unnecessary equipment, an annulus building ventilation system is no longer part of EPRI's design. The staff concludes that deletion of the annulus ventilation system from the evolutionary ALWR design does not conflict with regulatory requirements or guidance and is, therefore, acceptable.

8.4.4 PWR Auxiliary Building Ventilation System

Section 8.4.3 of Chapter 9 states that the PWR auxiliary building ventilation system will consist of the normal ventilation subsystem and the filtered exhaust subsystem.

The key requirements for the auxiliary building normal ventilation subsystem are the following:

- The subsystem will be designed as a non-safety-related non-seismic system powered from the permanent non-safety distribution system and equipped with safety-related, seismically qualified isolation dampers.
- The subsystem will be designed to perform the following functions:
  - maintain the general area temperature within the range given in Section 8.2.1.1.1 of Chapter 9
  - maintain the ambient pressure slightly below atmospheric
  - direct air flow from areas of lesser potential airborne contamination to areas of greater potential contamination
  - provide ventilation, cooling, and heating to all equipment in the auxiliary building, including the ESF compartments, during normal plant operation
  - provide filtered outside air to maintain the maximum permissible concentration levels in the cubicles within ALARA guidelines
  - provide filtered outside air to general areas
  - provide for a transit time of unfiltered exhaust air from the radiation monitors to the isolation dampers that is greater than the damper closing time plus the radiation monitor response time
- The supply subsystem will consist of a filter bank, an electric heating coil, cooling coils supplied by nonessential chilled water, and supply fans.
- The exhaust subsystem will consist of exhaust fans equipped with automatic flow controls.
- The normal ventilation subsystem will be manually controlled from a local panel provided with temperature and pressure indicators and fan status lights.
- On receipt of an ESF signal or a high-radiation signal at the unfiltered exhaust duct, the system design will ensure the following automatic actions: tripping of the normal ventilation subsystem, closing of the auxiliary building isolation dampers, and starting of the ESF compartment ventilation systems and the filtered exhaust subsystem.

The key requirements for the auxiliary building filtered exhaust subsystem are the following:

- The subsystem will be designed as a Safety Class 3, Seismic Category I subsystem with a Class 1E power supply.

- The subsystem will be designed to perform the following safety-related functions during accident conditions:

  - exhaust the required quantity of air to maintain a negative pressure of about 0.125-inch water gauge with respect to adjacent auxiliary building areas in the ESF compartments

  - filter the exhaust air before it is discharged to limit the offsite dose to the guidelines of 10 CFR Part 100

- The subsystem will be designed to operate during normal (i.e., non-ESF) plant operation to reduce undesirable levels of airborne contamination.

- The subsystem will be provided with two 100-percent-capacity divisions, each consisting of a bank of prefilters, a HEPA filter bank, an exhaust fan equipped with automatic volume control, and associated dampers, ducts, instruments, and controls. The Evolutionary Requirements Document does not require the provision of charcoal filters for the auxiliary building filtered exhaust subsystem. The staff's evaluation of the elimination of charcoal filters from any emergency filter unit is provided in Section 8.2.1 of this chapter and in Chapter 5.

- The subsystem control will be designed for automatic initiation on receipt of an ESF or high unfiltered exhaust air radiation signal and manual start from the main control room.

- A local control panel will be provided with all the switches, fan status lights, instrumentation, and alarms.

The Evolutionary Requirements Document indicates that, following a LOCA, only a small amount of air will be exhausted from the auxiliary building in order to achieve a negative pressure of about 0.125-inch water gauge within the auxiliary building. The amount of makeup air required can be drawn in through some predetermined openings. Therefore, EPRI states that the supply subsystem will not be needed and will not be designed as safety related. Because of the flexibility in system design, the staff will review the detailed system design and operation and facility layouts during its review of an individual application for FDA/DC to determine the need for a safety-grade supply system.

Pending resolution of the requirement for charcoal filters, the staff concludes that the design requirements (with the exception of the need for a safety-grade supply subsystem) in Section 8.4.4 of Chapter 9 for the PWR auxiliary building ventilation system do not conflict with the guidance in SRP Sections 9.4.3 and 9.4.5 and are, therefore, acceptable. However, the requirements by themselves do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

9 LABORATORIES

Section 9 of Chapter 9 of the Evolutionary Requirements Document provides the requirements for the laboratories (including counting rooms, cold chemistry facilities, and calibration facilities) of an ALWR plant. The primary functions of these laboratories are to provide (1) plant support services for routine health physics analysis, (2) normal and postaccident cold chemical analysis of required plant chemistry samples, (3) routine and postaccident counting of plant radioactivity samples, (4) grab sample analysis, and (5) a facility to store and secure radioactive calibration and check sources and instruments being calibrated or repaired.

Section 9.2 of Chapter 9 states that the laboratories will be sufficiently equipped to permit all critical onsite sampling specified in Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants To Assess Plant and Environs Conditions During and Following an Accident." The Evolutionary Requirements Document includes specifications for the plant sampling and laboratory facilities where normal and postaccident cold chemical and radioactive analyses are to be performed. The document requires that the plant designers ensure that suitable laboratory services, service connections, support equipment, and instrumentation are provided at the plant site. Moreover, Section 9.6 of Chapter 9 specifies that a computer system should exist for evaluating the collected data. The document also requires that a maintenance program be established for all the sampling and analytical facilities. EPRI states that the plant designer will provide a detailed description of the equipment and instrumentation to be used in these laboratories. To maintain doses to laboratory personnel as low as is reasonably achievable and to ensure reliable instrument radiation readings, radiation counting rooms, instrument calibration areas, and checkout areas will be located in low-radiation areas of the plant. Section 9.4 of Chapter 9 states that laboratory check and calibration sources will be secured in shielded storage areas to minimize radiation doses to laboratory personnel and to ensure that low levels of background radiation are maintained in counting room areas.

Item III.D.3.3 of NUREG-0737 states that licensees must provide equipment and associated training and procedures for accurately determining the airborne iodine concentration in areas in the facility where plant personnel may be present during an accident. Failure to address compliance with this item of NUREG-0737 was identified as an open issue in the DSER for Chapter 9. EPRI has revised Appendix B to Chapter 1 to require compliance with 10 CFR 50.34(f)(2)(xxvii) which addresses Item III.D.3.3 of NUREG-0737 on post-accident iodine sampling. The staff concludes that this is acceptable and will review individual applications for FDA/DC to ensure that vendors provide a list of specific equipment used to measure plant airborne iodine concentrations. Therefore, this DSER open issue is closed.

The staff concludes that the functions and design features of the laboratories comply with the guidance in Regulatory Guide 8.8 and SRP Section 12.5, "Operational Radiation Protection Program," and the Commission guidelines regarding the chemical engineering and radiation protection aspects related to the design and operation of the decontamination and the normal and postaccident sampling systems and are, therefore, acceptable. However, by themselves they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document must demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

10 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 9 of the Evolutionary Requirements Document for the design of site support systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the plant-specific design, operation, and arrangement of the site support systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 9 specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose site support systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 9 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
GENERIC SAFETY AND LICENSING ISSUES

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address the resolution of generic safety issues in Appendix B of each chapter. In the DSER for Chapter 9 the staff evaluated EPRI's requirements to address the resolution of Issue A-29, "Nuclear Power Plant Design for the Reduction of Vulnerability to Industrial Sabotage," and identified open and confirmatory issues associated with this issue. EPRI subsequently relocated its requirements to address A-29 to Appendix B to Chapter 1. The staff's evaluation of EPRI's requirements to address A-29 is given in Appendix B to Chapter 1 of this report. Therefore, these DSER open and confirmatory issues are closed.

CHAPTER 10, "MAN-MACHINE INTERFACE SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the results of the NRC staff's review of Chapter 10, "Man-Machine Interface Systems," of Evolutionary Requirements Document through Revision 3. Chapter 10 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering Nuclear Power; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Science Applications International Corporation; Westinghouse Electric Corporation; and EPRI.

On October 26, 1989, EPRI submitted the original version of Chapter 10 of the Evolutionary Requirements Document for staff review. By letters dated April 10, July 13, and August 2, 1990, the staff requested that EPRI supply additional information. EPRI provided the information in responses dated July 23, October 12, and December 6, 1990. Topic papers in Appendix B of the original version of this chapter were relocated to Appendix B of Chapter 1.

On October 8, 1991, the staff issued its DSER for Chapter 10 of the Evolutionary Requirements Document. On December 11, 1991, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 10, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 10, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 10 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 10

Chapter 10 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the man-machine interface systems (M-MIS).

The key topics addressed in the Chapter 10 review include EPRI-proposed design requirements for

- main control room design
- instrumentation and control system design
- computer applications
- human factors considerations

The staff's evaluation of the human factors aspects of both the man-machine interface systems and the other sections of the Evolutionary Requirements Document is provided in Appendix D of this chapter.

1.3 Policy Issues

During its review of Chapter 10 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of the this report.

1.4 Outstanding Issues

The DSER for Chapter 10 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) independence of the software verification and validation review teams (3.1.2, 3.1.4, and 6.1.5)

(2) use of commercial compilers for software used in safety systems (3.1.2)

(3) dedication of commercial-grade software (3.1.2)

(4) clarification of requirements for analysis and validation testing of M-MIS (3.1.3)

(5) prohibition on controls and displays in main control room (3.4.4)

(6) operator aids (3.4.5)

(7) establishment and use of reliability and availability estimates (3.5 and 3.5.4) difference between "practical" and "maximum degree practical" (3.5.3)

(8) component reliability of M-MIS (3.5.4)

(9) overall reliability of M-MIS (3.5.4)

(10) sneak circuit analysis (3.5.4)

(11) minimum tests for continuous on-line testing (3.6.1)

(12) guidance on use of simulators and mockups (4.1.3)

(13) vulnerability of power supplies for alarm systems (4.3.1)

(14) guidance on criteria to establish priorities (4.3.4)

(15) guidance on the maximum number of alarms (4.3.4)

(16) alarm sequence recording (4.3.4)

(17) guidance on frequency allocation plan (4.6)

(18) guidance on interference between communication systems and M-MIS equipment (4.6)

(19) use of dial up telephone-type portable radios for security purposes (4.6)

(20) environmental conditions for minimally used local control stations (4.9.2)

(21) guidance on inadvertent actuation of controls at local control stations (4.9.2)

(22) guidance on data system characteristics (5.2.2)

(23) expansion capability of multiplexers (5.2.3)

(24) reliability of multiplexing system (5.4)

(25) software design aids and tools (6.1.1 and 6.1.5)

(26) quality assurance requirements for safety-related software (6.1.2)

(27) configuration-management requirements for software (6.1.2)

(28) guidance on verification and validation plans (6.1.2 and 6.1.6)

(29) guidance on software user documentation (6.1.2)

(30) acceptance testing of commercially available software (6.1.2)

(31) notification of software errors or modifications of commercially delivered software products (6.1.2)

(32) long-term configuration control of software (6.1.2)

(33) clarification of top-down structured design approach (6.1.3)

(34) guidance on convolution of software structure (6.1.3)

(35) behavior of commercial software when assumptions are violated (6.1.3)

(36) diagnostic bypass during maintenance (6.1.3)

(37) guidance on memory protection (6.1.3)

(38) use of information by redundant safety channels (6.1.3)

(39) definition of reasonable testing and sufficient degree of confidence (6.1.5)

(40) specification of the level of diversity in safety systems (6.1.6, 6.2.3, and 6.2.5)

(41) guidance on performance of reliability evaluation (6.1.6)

(42) reference to Institute of Electrical and Electronics Engineers 1050-1989 (6.2.2 and 6.2.9)

(43) compatibility between M-MIS equipment and its external power supply systems (6.2.2)

(44) alarmed, self-diagnostic feature on clock update (6.2.3)

(45) guidance on position of sensor isolation valves (6.2.5)

(46) capacitance-type pressure sensors (6.2.5)

(47) minimal acceptance review criteria for isolation devices (6.2.6)

(48) voltage design of battery and dc system (6.2.8)

(49) standards for surge suppression (6.2.8)

(50) electromagnetic interference/radiofrequency interference (EMI/RFI) considerations for wiring shields (6.2.9)

(51) use of qualified isolators for wiring shields (6.2.9)

(52) splices in raceways (6.2.12)

(53) requirements for signal reconstruction (6.3.3)

(54) use of interrupts (6.3.3)

(55) redundancy of safety systems (6.3.4)

(56) selection of automatic or manual control (7.2)

(57) operation of plant by load dispatcher (7.3)

(58) continuous self-testing of actuation logic (8.3.2)

(59) security functions of M-MIS (10.2.1)

(60) radiation monitor placement, calibration frequency, and emergency power provisions (10.2.1)

(61) compliance with Item II.F.1-3 of NUREG-0737 (10.2.1)

(62) criteria for airborne reactivity monitors (10.2.1)

(63) manning of M-MIS that controls security functions (10.2.3)

(64) automatic reconfiguration of M-MIS that controls security functions (10.2.3)

(65) automatic self-testing feature of M-MIS that controls security functions (10.2.3)

(66) guidance on exceptions to independence criteria for electrical systems (Generic Safety Issues (GSIs) 2 and 110)

(67) 14-day maintenance criteria for M-MIS for reactor protection system, plant control system, and plant information and monitoring systems (GSI 75) (Appendix B)

(68) safety-related operator actions (B-17) (Appendix B)

(69) definition of local control stations (GSI HF 5.1) (Appendix B)

(70) functional centralization of local control stations (GSI HF 5.1) (Appendix B)

(71) human factors tests and evaluations of alarm systems (GSI HF 5.2) (Appendix B)

(72) inclusion of computer specialist on design and review teams (3.1 of Appendix D)

(73) organizational structure of the human factors function (3.1 of Appendix D)

(74) guidance on systems analysis (3.2.1 of Appendix D)

(75) guidance on organization of plant information (3.2.1 of Appendix D)

(76) location of valve position indication (3.3 of Appendix D)

(77) applicability of human factors guidelines for new technology (3.3 of Appendix D)

(78) illumination levels (3.3 of Appendix D)

(79) use of electronically displayed procedures (B.12 and 3.4 of Appendix D)

(80) development of maintenance procedures (3.4 of Appendix D)

(81) selection and qualification of plant personnel (3.5 of Appendix D)

(82) training requirements for top-level personnel (3.6 of Appendix D)

(83) requirement to develop human factors verification and validation test plans (3.7.1 of Appendix D)

(84) documentation of human factors test activities (3.7.2 of Appendix D)

(85) assessment of team performance (3.7.4 of Appendix D)

(86) reactor vessel level instrumentation system (Appendix E)

Confirmatory Issues

(1) intention of use (1)

(2) use of proven software and firmware (2.3)

(3) manual actuation control for automated systems (2.3)

(4) workstation redundancy (2.3)

(5) verification and validation of software tools in design plan (3.1.2)

(6) review of existing light water reactor M-MIS design problems (3.1.3)

(7) responsibility for generating software test plans (3.1.3)

(8) qualification of software-based on-board diagnostics and automatic testers (3.6.6)

(9) installation of spare cable conductors (3.8.2)

(10) operator action emergency timing (4.2.2, 8.2.3, and Appendix B)

(11) elimination of nuisance alarms (4.3.3)

(12) instrumentation for postaccident monitoring (4.4)

(13) testing for effects of EMI/RFI on safety and control electronics (4.6)

(14) use of antistatic carpet (4.7)

(15) unauthorized actuation of the remote shutdown stations (4.9.1)

(16) sabotage considerations regarding remote shutdown station controls that support normal operations (4.9.1 and 4.9.3)

(17) sabotage considerations regarding time required to prevent accidents resulting from unauthorized actions in a remote shutdown station (4.9.1 and 4.9.3)

(18) impact of support software on installed software (6.1.2)

(19) software common-mode failures (6.1.6)

(20) coordination of reactor and power generation control systems (6.2.2)

(21) tradeoff between the use of intelligent switch logic and hardware and software complexity (6.2.4)

(22) qualification of sensors (6.2.5)

(23) fiberoptic standards (6.2.6)

(24) bypass of thermal overloads of Class 1E motor-operated valves (6.2.7)

(25) removal of power to motor-operated valves to meet single-failure criterion (6.2.7)

(26) removal of NAMCO reference (6.2.7)

(27) manual valve position indication (6.2.7)

(28) internal and external leakage detection (6.2.7)

(29) non-Class 1E I&C distribution connections (6.2.8)

(30) failure indication differentiation (6.2.8)

(31) time period for automatic actuation (8.2.3)

(32) tradeoff in trip signal selection (8.3.2)

(33) compliance with rule on anticipated transients without scan (10 CFR 50.62) (8.3.2)

(34) tamper-proof reactor trip breakers (8.3.4)

(35) safety implications of instrumentation and control systems (Unresolved Safety Issue A-47, GSI 76) (Appendix B)

(36) BWR water level instrumentation (GSI 101) (Appendix B)

(37) deletion of Appendix C to Chapter 10 (Appendix C)

(38) connection of non-safety power supplies to the safety-grade power bus (6.2.8)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All issues identified in the DSER for Chapter 10 of the Evolutionary Requirements Document have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.10.V-1 software protection (2.3)

E.10.V-2 level of automation (2.3)

E.10.V-3 review of equipment used for displays to the operator (2.3)

E.10.V-4 methods to ensure operator alertness (2.3)

E.10.V-5 additional criteria for developing technology (2.3)

E.10.V-6 independence of verification and validation review teams (3.1.2)

E.10.V-7 use of commercial compilers for software used in safety systems (3.1.2)

E.10.V-8 dedication of commercial-grade software (3.1.2 and 6.1.2)

E.10.V-9 use of commercial-grade equipment (3.1.2)

E.10.V-10 complexity of M-MIS (3.1.3)

E.10.V-11 clarification of requirements for analysis and validation testing of M-MIS (3.1.3)

E.10.V-12 use of unproven technology (3.2.2)

E.10.V-13 operator aids (3.4.5)

E.10.V-14 quantitative reliability criteria (3.5)

E.10.V-15 establishment and use of reliability and availability estimates (3.5)

E.10.V-16 selection of equipment failure modes (3.5.1 and 6.2.7)

E.10.V-17 maintenance frequency (3.5.2)

E.10.V-18 reliability analysis (3.5.4)

E.10.V-19 component reliability of M-MIS (3.5.4)

E.10.V-20 overall reliability of M-MIS (3.5.4)

E.10.V-21 minimum tests for continuous on-line testing (3.6.1)

E.10.V-22 automatic reconfiguration after failure detection (3.6.4)

E.10.V-23 surveillance period of automatic testing features (3.6.8)

E.10.V-24 automatic bypass initiation (3.6.10, 3.6.13, and 3.6.14)

E.10.V-25 module software concerns (3.7.4)

E.10.V-26 bypass and test lockouts during on-line repairs (3.7.6)

E.10.V-27 guidance on use of simulators and mockups (4.1.3)

E.10.V-28 vulnerability of power supplies for alarm systems (4.3.1)

E.10.V-29 alarm suppression techniques (4.3.3)

E.10.V-30 guidance on criteria to establish priorities (4.3.4)

E.10.V-31 guidance on the maximum number of alarms (4.3.4)

E.10.V-32 guidance on frequency allocation plan (4.6)

E.10.V-33 guidance on interference between communication systems and M-MIS equipment (4.6)

E.10.V-34 unauthorized access to equipment in remote shutdown stations (4.9.1)

E.10.V-35 guidance on inadvertent actuation of controls at local control stations (4.9.2)

E.10.V-36 design of emergency operations facility (4.9.4)

E.10.V-37 modification of security boundaries during an emergency (4.9.4)

E.10.V-38 data storage methods (4.9.4)

E.10.V-39 compliance of perimeter intrusion alarm system with 10 CFR 73.55(h) (5.2.1)

E.10.V-40 guidance on data system characteristics (5.2.2)

E.10.V-41 signal transport delay (5.2.5)

E.10-V-42 acceptability of digital-to-analog and analog-to-digital convertors (5.7)

E.10.V-43 software requirement specification (6.1.2)

E.10.V-44 verification of software (6.1.2)

E.10.V-45 documentation of testing and verification of commercially available software (6.1.2)

E.10.V-46 acceptance testing of commercially available software (6.1.2)

E.10.V-47 configuration control of software purchased through software clearinghouses (6.1.2)

E.10.V-48 guidance on convolution of software structure (6.1.3)

E.10.V-49 behavior of commercial software when assumptions are violated (6.1.3)

E.10.V-50 guidance on memory protection (6.1.3)

E.10.V-51 separation of databases for redundant safety-related devices (6.1.3)

E.10.V-52 definition of reasonable testing and sufficient degree of confidence (6.1.5)

E.10.V-53 specification of the level of diversity in safety systems (6.1.6, 6.2.3)

E.10.V-54 specific methods used to meet the requirement for diversity (6.1.6)

E.10.V-55 elimination of EMI (6.2.2)

E.10.V-56 compatibility between M-MIS equipment and its external power supply systems (6.2.2)

E.10.V-57 signal validation methodology (6.2.2)

E.10.V-58 capacitance-type pressure sensors (6.2.5)

E.10.V-59 minimal acceptance review criteria for isolation device (6.2.6)

E.10.V-60 EMI/RFI considerations for wiring shields (6.2.9)

E.10.V-61 restoration state of control system components after loss of power (6.3.2)

E.10.V-62 setting resolution for control parameters (6.3.3)

E.10.V-63 requirements for signal reconstruction (6.3.3)

E.10.V-64 use of interrupts (6.3.3)

E.10.V-65 continuous self-testing of actuation logic (8.3.2)

E.10.V-66 radiation monitor placement, calibration frequency, and emergency power provisions (10.2.1)

E.10.V-67 compliance with Item II.F.1.3 of NUREG-0737 (10.2.1)

E.10.V-68 criteria for airborne radioactivity monitors (10.2.1)

E.10.V-69 14-day maintenance criteria for M-MIS for reactor protection system, plant control system, and plant information and monitoring systems (GSI 75) (Appendix B)

E.10.V-70 procedures to assess unscheduled reactor shutdowns (GSI 75) (Appendix B)

E.10.V-71 safety implication of instrumentation and control systems (USI A-47, GSI 76) (Appendix B)

E.10.V-72 inclusion of computer specialist on design and review teams (3.1 of Appendix D)

E.10.V-73 establishment of Q-list and associated equipment list (GSI 75) (Appendix B)

E.10.V-74 handling of vendor interface (GSI 75) (Appendix B)

E.10.V-75 evaluate neutron monitoring system M-MIS (7.4)

E.10.V-76 reliable operation of reactor trip breaker (GSI 75) (Appendix B)

E.10.V-77 design of BWR water level instrumentation (GSI 101) (Appendix B)

E.10.V-78 operator training and emergency operating procedures concerning feed-and-bleed operations (GSI 122.2) (Appendix B)

E.10.V-79 human factors organization (3.1 of Appendix D)

E.10.V-80 acoustical environments in operating control areas (3.7.6 of Appendix D)

E.10.V-81 Design reference documents include IEEE P1023/D5 (3.7.6 of Appendix D)

2

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

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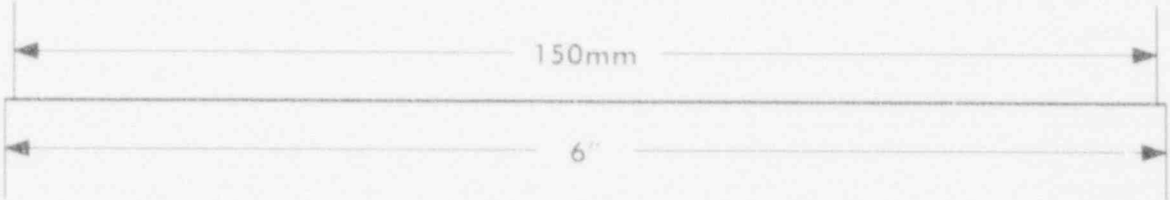
2

IMAGE EVALUATION TEST TARGET (MT-3)



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2

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

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2

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

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2 SCOPE, OBJECTIVES, AND POLICY STATEMENTS

2.1 Function and Scope

Section 1 of Chapter 10 of the Evolutionary Requirements Document states that each M-MIS will include, to some degree, equipment with the following functions:

- data gathering equipment that monitors equipment and process variables

- data communication equipment that transmits equipment and process variables between data processing equipment and plant equipment

- data processing equipment that manipulates data for use by plant operations personnel and/or automatic protection and control equipment

- plant information display and control equipment that provides alarm and display media for plant personnel to access plant processes and equipment status and controls to operate plant equipment

- output processing equipment that provides the necessary interfaces between plant controls and plant equipment actuators

As described in the other chapters of the Evolutionary Requirements Document, the interface between the fluid systems and the instrumentation system will be at the connection of the fluid system to the sensor. For control systems, the interface will be the connection to the final actuator wiring or tubing through which the power or control signals will be transmitted. EPRI's stated goal for this chapter is to provide design criteria that incorporate technological improvements and human factors considerations that will result in the resolution of problems experienced in operating reactors. The staff concludes that EPRI's definition of the M-MIS and the goals are acceptable.

Section 1 of Chapter 10 states that the scope of the Evolutionary Requirements Document includes all equipment regardless of supplying organization. Chapter 10 requirements are not all inclusive but are aimed at resolving specific problem areas or meeting specific utility objectives. The M-MIS covered by the Chapter 10 requirements include

- instrumentation, including sensors and local instruments, for all safety and non-safety systems throughout the plant

- automatic and manual controls for all safety and non-safety systems

- protection systems, including safety and non-safety systems

- diagnostic systems, including loose parts monitoring systems, rotating machinery diagnostics, and neutron noise monitoring

- monitoring and control stations for the plant systems, including the main control room, remote shutdown control station, technical support center, emergency operations facility, and local control stations (not every local control panel is specified, but requirements are provided regarding when local controls should be provided and for the consolidation and arrangement of these local controls into panels)

- instrumentation and control power supplies, grounding, and environmental compatibility

- computer systems for control, data acquisition, display, storage and retrieval, monitoring and alarms, technical support, and operations support

- plant communications systems, including data, visual, and voice intraplant communication associated with plant operation and maintenance

- a simulator for the design, verification, and validation of the M-MIS, but not for the simulator complex itself

2.2 Objectives

Section 2.1.1 of Chapter 10 of the Evolutionary Requirements Document requires that the M-MIS be designed to take full advantage of operator capabilities without challenging operator limitations and that the human component be specifically included in the design. Appendix D of this chapter contains the staff's evaluation of the human factors aspects of this section.

Section 2.1.2 of Chapter 10 states that the M-MIS design will be coordinated with the overall plant design. The staff agrees with this objective.

Section 2.1.3 of Chapter 10 states that the control, protection, and monitoring functions of the M-MIS will be designed with a consistent, integrated approach so that these functions work together to enhance plant operation and reduce operator burden. The Evolutionary Requirements Document requires that all control stations be integrated so that they perform as a coordinated whole and provide a consistent and easily understood and manipulated man-machine interface for plant operations and maintenance personnel.

The staff agrees with the objective of a consistent, easily understood M-MIS. However, the objective of integrated control stations in this section is vague. The staff does not specifically disagree with this objective, but it needs to be implemented by consideration of such requirements as segmentation, separation, and single-failure criteria. The staff discusses this issue further in Section 2.3 of this chapter under the heading "Main Control Room."

Section 2.1.4 of Chapter 10 requires that the M-MIS achieve very high reliability. Although it states that the M-MIS will be constructed of highly reliable components and equipment, be well analyzed, and be tested, the specific analyses and tests to be performed are not discussed. The M-MIS will be designed so that failures or problems in one function will not be able to propagate into other functions so that the extent of the upset will be minimized and the operator burden will not be increased. The staff agrees with this objective. The staff's evaluation of the EPRI reliability requirements is included in Section 3.5 of this chapter.

Section 2.1.5 of Chapter 10 specifies that maintenance considerations and possible future upgrades will be taken into account in the design of the equipment. The staff considers this to be an area that needs improvement over operating reactors and agrees with this objective.

2.3 Policy Statements

EPRI intends the policy statements in Section 2.2 of Chapter 10 of the Evolutionary Requirements Document to provide a summary view of the direction to be taken with regard to the requirements. These policies are discussed below. The criteria that EPRI is using in the Evolutionary Requirements Document to implement these policies are evaluated in subsequent sections of this chapter.

M-MIS Systems Approach

Section 2.2.1 of Chapter 10 requires that the M-MIS use modern digital technology and that it be robust, segmented, fault tolerant, and highly reliable. Redundant equipment within a segment will be separated, and protection against the propagation of failures will be provided. Some parameters will have signal validation. Multiplexing and fiberoptics will be used when appropriate. EPRI requires that hardware and software be standardized and modularized. The equipment will include self-diagnostics and will be compatible with the environment in which it is located. The staff concludes that these policies are acceptable.

Design Process

Section 2.2.2 of Chapter 10 states that the M-MIS design process will be directed by a single organization and will include utility engineering, operations, and maintenance personnel. A continuous verification and validation effort is to be performed in parallel with the design, by an independent team, with particular emphasis on software design. The staff finds this policy acceptable.

Reliability Inherent in Design

Section 2.2.3 of Chapter 10 states that the M-MIS should possess defense against the propagation of faults through segmentation, independence, and other measures. These systems also will be sufficiently robust to prevent a single failure from causing a forced outage. In its request for additional information dated April 10, 1990, the staff asked EPRI to describe the other measures to be used. It concluded that this requirement might be too vague to provide sufficient guidance for a designer to use effectively. It further noted that this requirement appeared to preclude an integrated control system (ICS) type of design. It asked EPRI to address the advantages of a segmented design over an integrated design.

By letter dated July 23, 1990, EPRI responded that the main purpose of segmentation is to prevent the propagation of failures. The statements in the Evolutionary Requirements Document are meant to encourage a vendor to take whatever measures are needed to attain the goal. EPRI also stated that the segmentation requirement would prohibit a Babcock and Wilcox (B&W) ICS in ALWR plants and that a highly interconnected ICS was not necessary to achieve adequate plant performance and was more vulnerable to problems from a single failure.

The staff concludes that these policies are acceptable. However, it does not preclude the use of a B&W ICS. Specific reliability issues are evaluated in Section 3.5 of this chapter.

Testing of Man-Machine Interface Systems

Section 2.2.4 of Chapter 10 states that the equipment used in the M-MIS will be designed to support inservice testing and specifically to avoid the use of lifted leads and jumpers. The staff considers this to be good practice and acceptable.

Proven Technology

In Section 2.2.5 of Chapter 10, EPRI encourages the use of modern digital technology to solve existing problems and make significant improvements over previous designs. To avoid introducing new problems, equipment that has been extensively used or tested will be used. The staff concludes that this policy is acceptable. Further, in its submittal dated July 23, 1990, EPRI committed to revise this section to include software and firmware in the requirements pertaining to proven technology. In the DSER for Chapter 10, the staff identified this as a confirmatory issue. The staff has verified that EPRI has revised this section to include software and firmware in the requirements pertaining to proven technology. Therefore, this DSER confirmatory issue is closed.

Operating Staff

Section 2.2.7 of Chapter 10 gives the number of people that the M-MIS control room design must accommodate. EPRI states that the number of licensed operators will be sufficient to satisfy the requirements of 10 CFR 50.54(m). The designer will verify the operator staffing levels using mockups and dynamic simulation. EPRI anticipates that one reactor operator will be able to control the plant during normal power operation. Additional information on operating staff is provided in Section 4.2 of Chapter 10 of the Evolutionary Requirements Document. In Appendix D of this chapter, the staff addresses the human factors aspect of this issue.

In its request for additional information dated April 10, 1990, the staff asked if expert systems or knowledge-based software was allowed or required to reduce operator burden and what the criteria would be for their use. The use of systems that might be considered expert systems is allowed in the Evolutionary Requirements Document. In its response dated July 23, 1990, EPRI stated that the criteria pertaining to need and the demonstrated capabilities required for the M-MIS will apply to any expert systems. This does not violate any existing NRC criteria and is acceptable. However, computer systems that are commonly referred to as "expert systems" or "artificial intelligence systems" will only be acceptable to the staff for use in safety systems when they can be shown to be highly reliable and when specific design and acceptance criteria are established. The staff will review software protection during its review of an FDA/DC application.

Human Factors Engineering

Section 2.2.8 of Chapter 10 states that significant emphasis will be placed on human factors during the M-MIS design process. Particular emphasis will be placed on

(1) elimination of potential sources of human error

(2) reduction in the probability of human error through careful selection and allocation of tasks

(3) provision for the detection of and recovery from human errors should they occur and the detection of errors before they affect the plant

The staff agrees that human factors should be considered during the design process rather than after. Appendix D of this chapter contains the staff's evaluation of this subject.

In its request for additional information dated April 10, 1990, the staff asked if Item 1 above was a requirement for the instrumentation and control system to be single failure proof. It also asked EPRI to explain how the goal of error detection before the errors affect the plant is to be reconciled with a reduction in anticipatory trips and simplification.

By letter dated July 23, 1990, EPRI responded that it is probably not possible to make a practical M-MIS that will be single failure proof, unless the systems are totally automatic. It considered operator error to be a factor that the designer must address. The primary method in the Evolutionary Requirements Document to reduce operator error is the basic improvement in human factors considerations during the design. In its response, EPRI also stated that it considered simplification to be consistent with reduction in operator errors because of ease of use. Although the staff agrees with the EPRI comment, it is aware that some vendors incorporate protection in their software programs to prevent incorrect operator actions such as exceeding a setpoint. The descriptions of these internal protection methods in the Evolutionary Requirements Document add additional complexity to the system. The benefits of these features, as well as other complexities (self-diagnostics), may provide significant safety gains and are acceptable, but the staff does not consider that such protection simplifies the system. Therefore, it will address the tradeoffs associated with the complexity of such software during its review of an FDA/DC application.

Level of Automation

Section 2.2.9 of Chapter 10 states that the designer will consider the system response requirements, complexity of operation, operator burden, level and duration of attention required, and so forth, when determining the proper level of automation. Operator awareness of plant status and operator alertness also must be considered. Automatic control systems should use fail-safe features when possible. The staff finds these policies acceptable; however, it will assess the level of automation during its review of an FDA/DC application.

Main Control Room

Section 2.2.10 of Chapter 10 states that the main control room (MCR) will be designed by an interdisciplinary control room design team that is a subset of the M-MIS design team. The MCR will be integrated and coordinated with facilities associated with other plant functions such as the engineering, maintenance, management, and emergency response facilities. Personnel in the MCR will use redundant, compact workstations with multiple electronic display and control devices that provide organized, hierarchical access to alarms, displays, and controls. Large, upright integrated plant status panels and top-level alarm displays viewable from anywhere in the MCR also will be used. Appendix D of this chapter contains the staff's human factors assessment of the MCR design process.

EPRI requires the designer to consider the use of multifunctional display and control features. An example provided by EPRI includes the use of a multi-functional control device for the operation of redundant safety trains and of both safety and non-safety equipment.

The Evolutionary Requirements Document requires that the equipment be designed to satisfy existing requirements such as Institute of Electrical and Electronics Engineers (IEEE) 279, IEEE 384, and Regulatory Guide 1.62, "Manual Initiation of Protective Actions." Regulatory Guide 1.62 stipulates that no single failure in the manual, automatic, or common portion of the protection systems should prevent initiation of protective action by manual or automatic means. The designer is required to use existing defensive measures as appropriate to ensure that the alarm, display, and control functions provided by the redundant workstations meet these standards. Methods given in the Evolutionary Requirements Document to meet these requirements include segmentation, separation, independence, diversity, fault tolerance, signal validation, self-testing, error checking, and supervisory watchdog programs.

EPRI requires that a supervisor's workstation be identical to the operator's workstation. Each workstation is required to include the following features:

- Electronically displayed normal, abnormal, and emergency operating procedures.

- Electronically displayed presentations of plant operational parameters and technical data based on operator tasks and event categories. The displays will include piping and instrument diagrams generated from computer-aided design software.

- Electronically displayed alarms designed to minimize nuisance alarms. Diagnostic aids also should be used.

- Controls that are coordinated with the decisionmaking approach. The controls do not need to be spatially dedicated.

A series of nonredundant, integrated upright displays and alarms will be placed on the MCR walls to provide a large plant mimic that will contain only a few key parameters.

In its request for additional information dated April 10, 1990, the staff stated that the use of a multifunctional control device for the operation of redundant safety trains and of both safety and non-safety equipment appeared to be a basic violation of all standards involving diversity, redundancy, separation, and defense-in-depth. By letter dated July 23, 1990, EPRI agreed that a multifunctional device could be constructed that would violate these requirements, but that the design approaches it intends to use would meet the requirements while providing a desirable compact workstation.

In its response, EPRI stated that the workstations will be redundant with any single station capable of providing all needed monitoring and control functions. In addition, EPRI stated that it would revise Section 4.5.6 of Chapter 10 of the Evolutionary Requirements Document to include a requirement that all automatically actuated safety functions have manual, conventional, hard-wired system-level actuation controls in the MCR. Information indicating that the systems have been actuated independent of the workstations also would be provided.

In the DSER for Chapter 10, the staff identified manual actuation control for automated systems as a confirmatory issue. The staff has verified that EPRI has revised the Evolutionary Requirements Document. This DSER confirmatory issue is closed.

In Section 2.2.10 of Chapter 10 of the Evolutionary Requirements Document, EPRI originally described the supervisor's workstation as normally disabled. In its request for additional information dated April 10, 1990, the staff asked EPRI to address the method used to verify operability of a normally disabled station. In its letter of July 23, 1990, EPRI committed to delete the paragraph and to provide an alternative text. The section would be changed to state that after the failure of any one workstation, two workstations will be available. Certain controls will be provided by conventional hard-wired methods. EPRI also committed to add sections to address workstation reliability, redundancy, and operability.

This was identified as a confirmatory issue in the DSER for Chapter 10. The staff has verified that EPRI has revised the Evolutionary Requirements Document as stated above. This DSER confirmatory issue is closed.

In its request for additional information dated April 10, 1990, the staff asked EPRI to define the phrase "electronically displayed." In addition, the staff asked why the top-level key parameter display for essential equipment is required to be nonredundant. The staff considered that little guidance was provided concerning the parameters that are to be displayed. By letter dated July 23, 1990, EPRI responded that the phrase "electronically displayed" was intended to encompass cathode-ray tubes, plasma displays, and liquid crystal displays. Specifically mentioned as items not included were meters, strip chart recorders, annunciator windows, and backlit indicators. EPRI stated that there was no need to make the overview board redundant, as the information presented would also be available at the workstations. The staff addresses the human factors aspect of the displays in Appendix D of this chapter. It will review the hardware and software aspects of the design in the instrumentation and control scope of review for the specific equipment selected during its review of an FDA/DC application.

In Section 2.2.10 of Chapter 10, EPRI describes measures to be taken to enhance operator alertness. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide additional information on how this was to be accomplished. In the letter dated July 23, 1990, EPRI referenced Section 3.4.2 of Chapter 10 of the Evolutionary Requirements Document and noted that further research was being conducted in this area. EPRI considers some methods used to maintain operator alertness to be beyond the scope of the Evolutionary Requirements Document. The staff will address this issue during its review of an FDA/DC application.

Other Control and Monitoring Stations

Section 2.2.11 of Chapter 10 states that the same design policies as those used for the MCR M-MIS will be used for the technical support center, emergency operations facility, remote shutdown station, local control stations, and other monitoring facilities. The Evolutionary Requirements Document states that the remote shutdown station will rely on local operation of some selected equipment.

In its request for additional information dated April 10, 1990, the staff asked EPRI to explain why some equipment would be excluded from the remote shutdown panel and what the exclusion criteria were. By letter dated July 23, 1990, EPRI responded that this section of the Evolutionary Requirements Document is only an overview of the remote shutdown characteristics and that the task analysis and requirements described in Sections 3.1.3.3.3 and 4.9.3.1 of Chapter 10 of the Evolutionary Requirements Document provide additional detail. In Appendix D of this chapter, the staff addresses this issue further.

Protection From Obsolescence

Section 2.2.12 of Chapter 10 notes that state-of-the-art instrumentation and control is constantly changing. The M-MIS will be modularized, and standardization will be used to prevent the obsolescence of the equipment. The staff concludes that this is acceptable.

Regulatory Stabilization

Section 2.2.13 of Chapter 10 states that even though EPRI expects the M-MIS to meet the existing regulatory requirements, many of these requirements do not consider the use of modern digital technology. EPRI considers that the evolution of the detailed M-MIS design may necessitate new implementation of the intent and purpose of existing guides and standards.

The staff agrees with the comments in this section. Although some new standards and regulatory guides (RGs) (e.g., RG 1.152, "Criteria for Programmable Digital Computer System Software in Safety-Related Systems of Nuclear Power Plants") that account for modern digital technology have been created, the standards and RGs in the area as a whole are still not abreast of the technology. Until such clear standards are in place, the staff expects that issues relevant to determining the safety of a plant that uses modern digital technology will be resolved through extensive discussions and reviews.

The staff also expects the M-MIS to be designed to meet the requirements of RG 1.153, "Criteria for Power, Instrumentation, and Control Positions of Safety Systems" (which endorses IEEE 603-1980, "Trial-Use Standard Criteria for Safety Systems for Nuclear Generating Stations"). The staff will use additional criteria as needed during its review of an FDA/DC application.

2.4 Conclusion

The staff concludes that, the requirements in Section 2 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and guidance and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

3 KEY REQUIREMENTS

The following sections describe both requirements proposed by EPRI and EPRI's rationale for each requirement. The staff considered the requirement and the rationale in its evaluation and used the same acceptance criterion (does not violate any NRC requirements) for the rationale as for the EPRI requirements.

3.1 M-MIS Design Process Requirements

Section 3.1 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS design will be established by a defined process that is to be systematic and consistent. The following sections provide greater detail on this requirement. The staff agrees with the general criterion to keep the design of the M-MIS under the control of a formal design process.

3.1.1 Overall Design Process Requirements

Section 3.1.1 of Chapter 10 requires that the M-MIS design meet the functional requirements without unnecessary complexity and without the use of unproven or highly developmental instrumentation or control strategies. The staff agrees with these requirements.

EPRI states that the M-MIS will be designed to emphasize the functional division of the plant rather than the traditionally used division according to physical systems. EPRI considers the basic functions to be reactivity control, reactor coolant pressure control, reactor coolant inventory and chemistry control, reactor core heat removal, and steam generator water level control (in PWRs). For other sections of the plant, EPRI states that the functional divisions will be control of energy flow, control of the local plant environment, control of the release of material to the environment, and provision of water, air, and electric power services.

The emphasis on functional design before system and equipment design is acceptable to the staff as long as the existing requirements are met. Some requirements, such as verification and validation and quality assurance, need early implementation.

Section 3.1.1.2 of Chapter 10 states that the M-MIS will be fully integrated with the remainder of the plant and that all modes of operation, including severe accidents, will be considered in the design. The staff agrees that some examples (insufficient heating, ventilating, and air conditioning) have shown that this area can be improved.

EPRI states that the M-MIS design will be applied consistently throughout the plant regardless of system, vendor, or safety classification. The staff agrees that a consistent application of design criteria is desirable. The staff addresses the human factors aspects of this section in Appendix D of this chapter.

3.1.2 M-MIS Design Organization and Plan

Section 3.1.2 of Chapter 10 provides criteria for the design organization and plan. It specifies that the design will be formally organized and directed by a single organization. Also, the designer will have broad experience in systems design and operation as well as instrumentation and control design. The designer may be an individual or a group.

Section 3.1.2.2 of Chapter 10 states that at least one individual design group will be created within the M-MIS design group for the MCR and should include

- engineers and designers for the nuclear steam supply system
- engineers and designers for the balance-of-plant systems
- human factors specialists
- utility engineering, operations, and maintenance staff

To achieve standardization, the staff considers that the inclusion of the utility in the design will require consensus, which does not currently exist between the various utilities on design, operations, and maintenance.

Section 3.1.2.3 of Chapter 10 states that the design process will include independent review of all aspects of the M-MIS design. Verification and validation (V&V) of the M-MIS design will be performed. The staff finds this acceptable. However, details regarding the independence of the review team are not given. This section also references Nuclear Safety Analysis Center (NSAC)-39, "Verification and Validation for Safety Parameter Display Systems," which allows several different methods for establishing review team independence. One acceptable approach listed in NSAC-39 is for the utility to perform the review. The staff notes that because the utility is required in the Evolutionary Requirements Document to be part of the design team, care will need to be taken to ensure that the utility had separate groups with this capability. The second acceptable approach would be to have a separate V&V contract with a firm experienced in V&V. A third acceptable approach listed in NSAC-39 is for the organization responsible for the development to perform or subcontract the V&V activities. However, individuals who do the V&V must not participate in the design or implementation of the M-MIS.

The guidance in NSAC-39 was intended for the non-Class 1E safety parameter display systems. The approaches listed in NSAC-39 and referenced as examples in the Evolutionary Requirements Document are acceptable to the staff provided additional clarification is added to ensure that, for safety systems, the verifier will be responsible to an organizational supervisor other than the designer. The independence of the V&V organization is very important and will provide a higher level of assurance that the verifier is sufficiently removed from the schedule and budget constraints of the design process and will remain independent.

In the DSER for Chapter 10, the staff identified independence of the software V&V review teams as an outstanding issue. In its response dated January 28, 1992, EPRI stated that it would modify Section 3.1.4 of Chapter 10 to require the review team to be technically, managerially, and financially independent of the design team. This is an important part of good V&V, and EPRI's clarification and inclusion are acceptable. Therefore, this DSER open issue is closed.

In addition, the staff will review details of the quality assurance program of the designer to ensure that sufficient independence of each review team is maintained. The staff's evaluation of the human factors aspects of this section is contained in Appendix D of this chapter.

Section 3.1.2.4 of Chapter 10 states that the designer will prepare a comprehensive plan for the development and implementation of the M-MIS design that at least includes

- a schedule with milestones
- a configuration control plan for the design and design tools
- an M-MIS/plant systems interaction plan
- provisions for utility participation

In its request for additional information dated April 10, 1990, the staff asked EPRI to address the qualification requirement for compilers, test equipment, on-line diagnostics, and so forth. The staff asked if this software will receive the same V&V as the safety function software. In a letter dated July 23, 1990, EPRI responded that this section will be revised to address software tools in the design plan.

In the DSER for Chapter 10, the staff identified V&V of software tools in the design plan as a confirmatory issue. The staff has verified that EPRI has revised the Evolutionary Requirements Document to address software tools in the design plan. This confirmatory issue is closed.

In its July 23, 1990, letter, EPRI also stated that requiring designers to provide compilers for the application software would probably result in the designer developing a compiler for this special use, rather than using an existing, well-proven compiler. The staff agrees that using a compiler with extensive commercial use may produce more reliable software than a special-use compiler.

In the DSER for Chapter 10, the staff identified the use of commercial compilers for software used in safety systems as an open issue. In its response dated January 28, 1992, EPRI stated that Section 6.1.3.10 of Chapter 10 requires compilers, operating systems, and other supporting software to be chosen from commercially available proven software packages. The requirement also prohibits choosing a new or untried software package. This is acceptable because it does not conflict with current regulatory guidance. In general, the staff agrees with EPRI's intent; however, the dedication of commercial products (including the items in this section) for use in safety systems is a topic that the staff will evaluate during its review of each FDA/DC application until acceptable generic guidance for the dedication of commercial software is endorsed by the staff.

Dedication of commercial-grade equipment for use in safety systems has been an area of concern to the staff. Problems have included processing methods and vendors who misrepresent the capabilities or qualification of their equipment. A more comprehensive discussion of past concerns and actions can be found in NRC Generic Letter (GL) 89-02, "Actions To Improve the Detection of Counterfeit and Fraudulently Marketed Products," and GL 91-05, "Licensee Commercial-Grade Procurement and Dedication Programs." These past problems have been experienced with equipment with significantly longer operating histories than the microprocessors and other newer equipment used in the M-MIS. In its request for additional information dated April 10, 1990, the staff asked EPRI to describe the method that will be used to determine if past design work on commercial-grade equipment was done properly and can be used for nuclear safety system applications to take advantage of proven designs. The staff also asked if reverse engineering (determination of requirements from the end product) is an appropriate method for software development. By letter dated July 23, 1990, EPRI responded that the intent of the requirement pertaining to proven design is to discourage the use of components that have a short operational history. In the DSER for Chapter 10, the staff concluded that this was a good design philosophy, but it would evaluate design-specific implementation for specific products during its review of an FDA/DC application. Therefore, this DSER open issue is closed.

The staff believes that it is possible to establish a realistic threshold where experience with the operation of software substitutes for documented V&V. However, this threshold is difficult to determine without a specific design to evaluate. No program is in place that would ensure that the end users and the staff are apprised of any problems caused by changes to commercial-grade software tools and other functional software. Section 3.1.2 of Chapter 10 of the Evolutionary Requirements Document is acceptable because it contains nothing that is in violation of NRC requirements. However, it does not contain requirements for the dedication of commercial-grade equipment for use in safety systems. In the DSER for Chapter 10, the staff concluded that EPRI should provide guidelines for the dedication of such equipment and identified this as an open issue. In its response dated January 28, 1992, EPRI stated that EPRI NP-5652, "Guideline for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications (NCIG-07)," had been added as requested by the NRC. It also stated that EPRI, the utilities, and others have embarked on a program to develop the qualification of commercial-grade programmable logic controllers and guidelines for the dedication of commercial-grade software. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will evaluate this item in detail during its review of an FDA/DC application.

3.1.3 Required Design Process Features

Section 3.1.3 of Chapter 10 states that the M-MIS design will ensure that problems with existing M-MIS designs are identified and features are incorporated in the ALWR M-MIS that provide satisfactory solutions of these problems. The designer will include the following in the design process:

- a comprehensive review at the beginning of the design process of existing LWR M-MIS designs to identify problems that have led to low plant availability and high maintenance burdens

- identification in the final M-MIS design of how each of the problems has been solved

Several references are provided as sources of the information required. In its request for additional information dated April 10, 1990, the staff asked EPRI to describe in more detail the type of review to be performed. In its response dated July 23, 1990, EPRI stated that it would revise this section to provide more detail on the scope of the reviews. It stated that the review will be comprehensive and systematic; will cover safety, availability, and maintenance problems; and will include an assessment of the applicability of each identified problem to the current design. The independent review required in Section 3.1.4 of Chapter 10 will explicitly cover the identification, assessment, and solutions of issues identified in this review. The staff's evaluation of the human factors aspects of this section is provided in Appendix D of this chapter.

In the DSER for Chapter 10, the staff identified the review of existing LWR M-MIS design problems as a confirmatory issue. The staff has verified that EPRI has provided more detail on the scope of the reviews. Therefore, this DSER confirmatory issue is closed.

Section 3.1.3.2 of Chapter 10 requires that the following actions be taken in the design process to achieve a simple, plant-wide standardized design:

- Prepare guidelines for standard design practice.
- Use standard component and systems designations.
- Track the numbers and types of components.

In its request for additional information dated April 10, 1990, the staff asked EPRI to show that the simplification and standardization of the plant do not compromise the defense-in-depth principles of General Design Criterion 22 of Appendix A to 10 CFR Part 50. The staff was concerned that equipment standardization within a single plant could reduce the diversity that exists in past designs.

By letter dated July 23, 1990, EPRI responded that there is no inference that safety should be compromised to achieve its goals and described the positive aspects of simplification, standardization, and segmentation. However, the extensive use of computer-based systems did not appear to the staff to be a simplification in the area of instrumentation and control. EPRI also noted that the advanced technology planned for the ALWR M-MIS will be more complex than current systems when measured by numbers of components. There is extensive experience, in particular with foreign reactor projects, that demonstrates that these new designs are more complex than past designs and require significant rigor in design control, such as strictly implemented V&V. The staff does not discourage the use of computer-based systems because there appears to be a real potential for increases in safety for the reasons given throughout Chapter 10 of the Evolutionary Requirements Document. The staff will evaluate the acceptability of the level of complexity of the system design during its review of an FDA/DC application.

In the DSER for Chapter 10, the staff noted that the standardization referred to in this chapter of the Evolutionary Requirements Document referred to the use of standard equipment within a single plant. This chapter did not address the 10 CFR Part 52 issue of a standard design that would be a single total design implemented at more than one site. The staff concluded that the Evolutionary Requirements Document did not necessarily require future plants to be of the same design in the M-MIS area. However, there are no requirements in the Evolutionary Requirements Document that would specifically preclude standard plant designs.

In its request for additional information dated April 10, 1990, the staff stated that design standards and practices should be established before the beginning of the design process. Section 3.1.3.2 of Chapter 10 states that the design process will provide for the preparation of guidelines for standard design practices. In its letter dated July 23, 1991, EPRI defined "design practices" as detailed rules and not general guidelines for design. EPRI further stated that use of new technology will require the testing and evaluation of many alternatives before the design practices are selected.

Section 3.1.3.3 of Chapter 10 states that the M-MIS design process will result in the explicit identification of the functions needed and the individual tasks needed to perform the functions. The functions and tasks will include all of those that affect the design and will be analyzed and validated using methods and equipment including mockups, modeling, and a full-scale simulator.

The following list is a minimum set of functions, identified in Section 3.1.3.3.3 of Chapter 10, that will be provided:

- allocation of functions between automatic and manual control
- allocation of tasks among workstations
- development of control and operation strategies
- assignment of responsibilities of the operating crew
- assessment of operator mental and physical workload
- selection of types of displays and their detailed characteristics
- selection of types of controls
- selection and arrangement of alarms and their integration into the control station designs
- development of operating procedures and training requirements
- evaluation of the effects of credible M-MIS equipment failures
- verification and validation reviews

The identified tasks and functions, including the bases for the allocations, will be documented.

Section 3.1.3.4 of Chapter 10 states that the potential for and the consequences of failures of plant and M-MIS components will be explicitly considered in the M-MIS design process. The functions and tasks required of the operator when equipment fails are to be identified. The analysis and validation testing of the M-MIS will include the failures and recovery from them. In the DSER for Chapter 10, the staff concluded that the clear indication of such failures and the effects of any cascading or interaction failures should also be considered and identified clarification of requirements for analysis and validation testing of M-MIS as an open issue. In its response dated January 28, 1992, EPRI stated that Sections 3.1.3.3.3 and 3.1.3.4 of

Chapter 10 require that the failures of components be explicitly considered in the M-MIS design process. They also require that the functions and tasks that result from the operator coping with equipment failures be identified as part of the M-MIS design bases. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will evaluate this issue during its review of an FDA/DC application.

Section 3.1.3.5.1 of Chapter 10 states that the design process will include the development of digital computer-based dynamic models for the overall plant response as well as individual control systems. These dynamic models are required to be

- suitable for analyzing both steady-state and transient behavior
- used to confirm the adequacy of control schemes
- used to confirm the allocation of control to an automatic system or an operator
- used to develop and validate plant operating procedures
- validated against tests of actual plant behavior, wherever practicable
- developed early enough in the design process that the systems can be modified if necessary
- incorporated into the simulators
- documented

In its request for additional information dated April 10, 1990, the staff asked EPRI to supply information concerning dynamic models and validation testing. By letter dated July 23, 1990, EPRI stated that the dynamic models will receive the same level of V&V as other design programs. EPRI's statement that the validation of the models against actual plant behavior is to be performed "whenever practical" is intended only to eliminate tests that cannot be performed at the actual plant, such as under severely degraded conditions. The staff expects that confirmatory measurements during startup to validate software algorithms will be required, and EPRI indicates that it does not intend to eliminate this validation step. The staff concludes that this is acceptable. The staff's evaluation of the human factors aspects of this section is provided in Appendix D of this chapter.

Section 3.1.3.5.2 of Chapter 10 states that the control systems will be analyzed to ensure stability and correct response. Delays in signal propagation will be considered.

Section 3.1.3.6.1 of Chapter 10 states that the design process will define the test requirements in formal test plans. The test plans will include the original validation testing, operational tests, and post-maintenance tests. As a minimum, each test plan will

* identify the items to be tested
* identify any features that are not to be tested and the reasons why
* describe the test approach
* specify the test case specifications
* specify the acceptance criteria
* specify the test environment
* specify the test equipment
* identify the group performing the test
* identify the test staffing requirements
* specify the test sequence and schedule

EPRI requires the designer to define and write the formal test plans. In its request for additional information dated April 10, 1990, the staff stated that most V&V and testing programs do not allow programmers to test their own software at the formal test stage, although the developer should be required to do testing during the development phase. Someone other than the developer should decide if the requirements and goals of the software have been met, although any testing that is recommended by the developer should be performed during formal testing. The staff agreed with the requirement that the developer review and correct the results of the testing. By letter dated July 23, 1990, EPRI responded that Section 6.1.5.7 of Chapter 10 of the Evolutionary Requirements Document requires the testing of the software to be independent of its development. It stated that it would modify Section 6.1.5.7 to clarify the responsibility for generating software test plans.

In the DSER for Chapter 10, the staff identified responsibility for generating software test plans as a confirmatory issue. The staff has verified that EPRI has modified Section 6.1.5.7 to clarify this responsibility. Therefore, this DSER confirmatory issue is closed.

Section 3.1.3.6 of Chapter 10 states that any inservice surveillance testing required to ensure equipment operation or to meet NRC requirements will be included in the previously listed test plans. Installation and startup tests also will be included in these test plans. The staff's evaluation of the human factors aspects of this section is included in Appendix D of this chapter.

3.1.4 Independent Review of Design Process

Section 3.1.4 of Chapter 10 requires an independent review that includes verification and validation as well as an overview of the entire design process. As discussed in Section 3.1.2 of this chapter, the independence of the review team must be specified to be acceptable to the staff.

Section 3.1.4.1 of Chapter 10 states that the reviewers will have technical qualifications comparable to those of the designers. This is in accordance with American National Standards Institute/Institute of Electrical and Electronics Engineers/American Nuclear Society (ANSI/IEEE/ANS) 7-4.3.2-1982, "Application Criteria for Programmable Digital Computer Systems in Safety Systems of Nuclear Power Generating Stations," and is, therefore, acceptable.

EPRI requires that a preliminary review plan be established before the design process is initiated. The final review plan will be established jointly by the designers and the reviewers. The independent review will start when the design process is started and will continue through final testing.

Section 3.1.4.4 of Chapter 10 states that the reviewer will verify that the M-MIS and plant systems functional requirements are met and that the hardware and software specifications will satisfactorily implement the functional requirements. The reviews will address

- simplicity
- standardization
- reliability and availability
- protection against common-mode failures
- power supply failures and their effects
- compatibility with the environment, including
  - temperature
  - humidity
  - radiation
  - radiofrequency interference
  - electromagnetic interference
  - vibration and seismic loadings
  - fire and fire suppression systems
  - flood
  - electrical transients and surges
- maintainability
- human factors for operators and maintenance personnel
- protection against obsolescence
- flexibility and expandability
- constructibility

The staff concludes that consideration of these items in the design review is good engineering practice and is acceptable. The staff's evaluation of the human factors aspects of this requirement is contained in Appendix D of this chapter.

EPRI states that the review team will review the system and component test plans, witness the tests, and review the test results. The review team is required to review the completeness and accuracy of the design documentation. It will also document its reviews and any deficiencies discovered. The staff's evaluation of the human factors aspects of this requirement is provided in Appendix D of this chapter.

3.2 Proven Technology

Section 3.2 of Chapter 10 of the Evolutionary Requirements Document states that proven technology will be used except when not available. In those cases, the use of advanced systems and equipment may be justified if proven in other applications.

3.2.1 Criteria for Proven Technology

Section 3.2.1 of Chapter 10 includes a reference to Section 11.2.1 of Chapter 1 of the Evolutionary Requirements Document, which defines proven technology as an item that has been used for several years in LWR plants or is otherwise specifically proven by the utility to be suitable for the application. Chapter 1 also allows the use of unproven technology, if justified. Section 3.2.1 of Chapter 10 states that in addition to the Chapter 1 definition, M-MIS equipment will be considered proven if (1) it has at least 3 years of documented, satisfactory service as modules of subsystems in power plant or non-power plant applications similar to that in LWRs or (2) it has undergone a defined program of prototype testing.

EPRI states that the primary emphasis of the ALWR is reliable power production. The staff concludes that EPRI's definition of proven technology is acceptable provided all the Commission's safety requirements also are met.

3.2.2 Criteria for Use of Unproven Technology

If a defined gain in simplicity or performance is needed that cannot be obtained with proven equipment, Section 3.2.2 of Chapter 10 allows the use of unproven equipment if testing or experience data justify it. The staff will evaluate the acceptability of the use of such equipment during its review of an FDA/DC application.

3.3 Cost

Section 3.3 of Chapter 10 of the Evolutionary Requirements Document states that the costs of the M-MIS will be consistent with the same general cost guidance in Chapter 1 as that for other equipment, with an emphasis on total life cycle and plant availability considerations instead of simple initial cost considerations. Although cost considerations are outside the scope of its review, the staff considers that the emphasis on long-term reliability and maintenance considerations is a positive goal.

3.4 Operator Actions

Section 3.4 of Chapter 10 of the Evolutionary Requirements Document states that the operator and other plant personnel are to be considered in the M-MIS design. The staff's comments on this section are given in Appendix D of this chapter.

3.4.1 Operator Workload

Section 3.4.1 of Chapter 10 states that the M-MIS design will not require the performance of tasks that would overburden the operators during normal, upset, or emergency conditions.

3.4.2 Operator Vigilance

Section 3.4.1.2 of Chapter 10 states that the M-MIS will be designed with features that will facilitate operator activities and tend to keep operators alert and attentive. The Evolutionary Requirements Document requires the application of the guidance provided by EPRI NP-6748. In the rationale, EPRI notes that the industry is studying the issue of operator vigilance and additional guidance will be available in the future.

3.4.3 Selection of Automatic or Manual Control

Section 3.4.3 of Chapter 10 states that the criteria for choosing between automatic and manual control operation will include consideration of

- operator workload
- operator capability
- experience
- operator vigilance
- complexity of hardware and software
- maintenance and testing burden
- consequences of and potential for malfunctions
- regulatory requirements

The staff concludes that consideration of these items is appropriate.

3.4.4 Selection of Remote or Local Control

Section 3.4.4 of Chapter 10 states that the selection of local versus remote (main control room) control will include consideration of

- operator workload and access time
- operator capability and monitoring needs
- local environment
- local monitoring needs
- complexity, maintenance, and testing burden
- malfunctions of remote equipment
- experience

The staff concludes that consideration of these items is appropriate. The staff's evaluation of the human factors aspects of this section is provided in Appendix D of this chapter.

In this section, EPRI originally stated that Section 4.9.1.2 of Chapter 10 specifically prohibits controls and displays in the main control room unless they support a defined task for the control room operators. However, Section 4.9.1.2 appeared to address main control room location and access, and the staff could not find the specific prohibition mentioned above. In its request for additional information dated May 17, 1991, the staff stated that the reference should be changed to Section 4.9.1.1.

In the DSER for Chapter 10, the staff identified the prohibition on controls and displays in the main control room as an open issue. In its response dated January 28, 1992 to the request for additional information, EPRI stated that it would change the reference in Section 3.4.4 of Chapter 10 from 4.9.1.2 to 4.9.1.1. EPRI made this change in Revision 3 of the Evolutionary Requirements Document. Therefore, this DSER open issue is closed.

3.4.5 Operator Aids

Section 3.4.5 of Chapter 10 states that the design will specify features for operator assistance. These aids will be in the form of computer-aided cathode-ray tube displays and permanently posted information. The designer also will evaluate the incorporation of active systems that will predict the consequences of a potential action. The staff's evaluation of the human factors aspects of this section is provided in Appendix D of this chapter.

In the DSER for Chapter 10, the staff concluded that EPRI should provide more guidance on the intentions and limitations of this requirement and identified operator aids as an open issue. In its response dated January 28, 1992, EPRI stated that the intention of this requirement is to encourage useful operator aids and to avoid operator aids that are distracting to the operator. EPRI also stated that the limitations of this requirement are as follows: operator aids must be related to a specific task, operator aids must be considered an integral part of the overall M-MIS design, and operator aids are required to be included in all evaluations of control station and M-MIS designs. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will review this item during its review of an FDA/DC application.

3.5 Availability and Reliability

Section 3.5 of Chapter 10 of the Evolutionary Requirements Document states that the designer will establish quantitative reliability and availability criteria for the component parts and subsystems of the M-MIS.

In its request for additional information dated April 10, 1990, the staff asked EPRI to explain how the quantitative reliability and availability criteria are to be determined. By letter dated July 23, 1990, EPRI responded that the estimates of core damage ($\leq$ 1E-5) and overall plant availability (87 percent over the life of the plant) are provided in Chapter 1 of the Evolutionary Requirements Document and it is up to the designer to allocate the reliability and availability to the various systems. The Evolutionary Requirements Document does not describe how these estimates, especially of software reliability, will be made with regard to the instrumentation and control design. It is not clear how these criteria will be established or used along with other defense-in-depth concepts to ensure adequate safety.

In the DSER for Chapter 10, the staff identified the establishment and use of reliability and availability estimates as an open issue. In its response dated January 28, 1992, EPRI stated that software reliability is achieved by the quality of the design, which is the product of a rigorous design process. EPRI also stated that the rigorous design process ensures that the contribution of software errors to component and subsystem reliability is insignificant. This is acceptable because it does not conflict with current regulatory guidance. The staff agrees that this is a very difficult subject for which detailed guidance cannot be established. Therefore, this DSER open issue is closed. However, the staff will evaluate this item during its review of an individual application for FDA/DC.

3.5.1 Effects of Postulated M-MIS Failures

Section 3.5.1 of Chapter 10 requires that the designer perform a case-by-case evaluation of plant equipment and select the appropriate failure state on loss of power. It states that typically the protection systems' preferred failure should be the safe condition. The control system will typically be designed to fail to the most stable state. Protection systems will not change state when power is restored and will initialize to manual control. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide additional justification for the initialization requirements. The staff concluded that the protection systems should always, not typically, fail to the safe state. The determination of what the safe state is at all times may be difficult to establish in some cases. The rationale provided by EPRI that the fail-safe requirements in the past were implemented in such a way that the plant was in a safe mode only from a limited regulatory perspective did not appear to the staff to provide guidance to the designer on how to determine the safe state for any particular equipment. In its letter of July 23, 1990, EPRI stated that the designer will select, on a case-by-case basis, the appropriate failure state. Therefore, the staff will evaluate the failure modes selected by the designer during its review of an FDA/DC application.

The Evolutionary Requirements Document requires that, to the extent practicable, the M-MIS and support equipment be single failure proof, including the capability for the on-line diagnostics and testing.

3.5.2 Top-Level Reliability Requirements

Section 3.5.2 of the Chapter 10 requires the mean time between forced outages caused by multiple random failures to be 50 reactor operating years or more. This requirement includes any outages required to avoid violation of technical specifications. The mean time between failures of the M-MIS equipment that result in the reduction of plant availability will be 5 years or more.

EPRI states that the mean time between failures that require corrective maintenance will be 14 days or more for the protection, plant control, and plant information and monitoring systems. In its request for additional information dated April 10, 1990, the staff asked if this section means that corrective maintenance of the protection system every 14 days is acceptable. By letter dated July 23, 1990, EPRI responded that the 14-day requirement is intended to include checks and potential adjustments or repairs that would be indicated by the self-testing or self-diagnostics. The staff will evaluate the acceptability of the maintenance program during its review of an FDA/DC application. This matter is discussed further in Appendix B to Chapter 1 of this report.

3.5.3 Design Requirements for Availability and Reliability

Section 3.5.3 of Chapter 10 provides guidance for segmenting M-MIS control and monitoring systems to protect against failures of M-MIS equipment. Segmentation is a major design requirement for the EPRI ALWR. If segmentation is not achieved, then EPRI's functional requirement to prevent propagation of unforeseen failures requires alternative design approaches that the designer must specifically identify and justify. EPRI states its intent to extend the segmentation and separation currently required for the safety and protection systems to the control and monitoring functions. The staff agrees with EPRI that this will improve the defense-in-depth aspects of the plant. Segmentation mitigates the reduction in the defense-in-depth from that in the existing analog designs that could result if central computers were used. The staff concludes that the guidance for achieving this requirement does not conflict with current regulatory requirements and is acceptable.

Table 10.3-1 of Chapter 10 provides a list of control and monitoring functions that are required to be segmented. There are no specific NRC requirements for the segmentation of control systems; therefore, these are acceptable. However, these EPRI requirements prohibit an integrated control system, such as those used in reactors designed by Babcock and Wilcox.

Section 3.5.3.1 of Chapter 10 states that for each of the segments listed in Table 10.3-1, different sets of sensors, transmitters, and data communication paths will be used when possible. Cross-checking or calibration and compensation between functions are allowed if the designer ensures that a complete failure in the instrumentation for one segment does not prevent the receiving control function of another segment from performing adequately.

In addition, EPRI states that for each segment, different processors and power supplies will be used whenever practicable. In its request for additional information dated April 10, 1990, the staff asked if the different processors would be diverse. By letter dated July 23, 1990, EPRI responded that the different processors do not need to be diverse but simply a different physical piece of equipment. This is acceptable to the staff for the purposes of segmentation within a safety train. However, many of the other sections in this chapter describe the need for diversity in the design of the safety systems.

EPRI also requires that, whenever practicable, data processing and data communication electronic equipment be housed in separate enclosures. Equipment for segmented functions may share a common room. The staff notes that in addition to the requirements of this section, EPRI also committed to meet physical-separation regulatory criteria, such as those in Appendix R to 10 CFR Part 50 and Regulatory Guide 1.75, "Physical Independence of Electrical Systems."

The different segments are to be provided with separate power supplies and housed in separate enclosures to the maximum degree practical. In the DSER for Chapter 10, the staff noted that EPRI did not differentiate between "practical" and "maximum degree practical." It requested that EPRI clarify the distinction between these two terms and identified the definition of "practical" and "maximum degree practical" as an open issue. In its response dated January 28, 1992, EPRI stated that the word "maximum" was used to add special emphasis to the statement. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will address the designers' use of the word "practical" during its review of an FDA/DC application.

EPRI states that segmentation of the M-MIS is intended to mimic the plant system segmentation. As discussed above, the existing regulatory criteria still apply, and in addition, the segmentation guidelines in the Evolutionary Requirements Document will apply for safety systems.

Section 3.5.3.3 of Chapter 10 states that the equipment will be designed for the environment in which it will be installed and that passive methods and robust hardware are preferred. In the rationale, EPRI notes that the reliability of the M-MIS equipment is sensitive to temperature and humidity; therefore, it requires that a means be provided to alert plant operators to a loss of environmental control. The design of the M-MIS will be such that as long as the heating, ventilating, and air conditioning (HVAC) system is restored within 1 hour of failure, there will be no loss of function and no maintenance of M-MIS components will be required. EPRI has committed to meet the requirements of 10 CFR 50.63 (station blackout rule) in Chapter 1 of the Evolutionary Requirements Document. This may involve longer times when the HVAC system is not operable than those assumed in this section.

3.5.4 Reliability and Maintainability Analysis

Section 3.5.4 of Chapter 10 states that the designer will perform analyses to predict the reliability of the M-MIS. These reliability analyses are to be consistent with MIL-HDBK-338, "Electronic Reliability Design Handbook," and MIL-HDBK-217E, "Reliability Prediction of Electronic Equipment." In the rationale, EPRI notes that these analyses are required to demonstrate that the M-MIS design meets the quantitative reliability and availability goals. In addition, Chapter 1 of the Evolutionary Requirements Document states that the M-MIS will meet the requirements of Section 5.3 of IEEE 603 regarding qualitative reliability goals for safety systems.

In its request for additional information dated April 10, 1990, the staff questioned the use of only these reliability analyses guidelines because they address the hardware issues but do not adequately address software reliability. In its response dated July 23, 1990, EPRI stated that reliability values have been given and will be met. However, the staff will evaluate the design-specific analysis during its review of an application for FDA/DC.

Section 3.5.4.1 of Chapter 10 requires the designer to use the component reliability data in MIL-HDBK-217E or an equivalent source to quantitatively determine the mean time between failures. The resultant analyses will be independently verified. In the DSER for Chapter 10, the staff concluded that the use of this method alone was not acceptable because the components for the M-MIS are substantially software-based digital systems and identified component reliability of the M-MIS as an open issue. In its response dated January 28, 1992, EPRI stated that the reliability analysis and component reliability required in Section 3.5.4 are intended to be applied to hardware components only. As discussed above, software quality is addressed through the software design process. This is acceptable because it does not conflict with current regulatory guidance; however, software reliability is an important consideration in assessing the reliability of digital systems. Therefore, the staff will evaluate this item during its review of an individual application for FDA/DC. This DSER open issue is closed.

EPRI states that the designer will perform reliability tests if adequate reliability data are not available in MIL-HDBK-217E or other equivalent sources. The general methodology for performing these tests is provided in MIL-STD-781, "Reliability Test Methods, Plans, and Environments of Engineering Development, Qualification, and Production." MIL-HDBK-338 will be used as a guideline for the statistical analysis. In the DSER for Chapter 10, the staff concluded this method was acceptable for determining the reliability of the hardware components but did not consider it acceptable for determining overall M-MIS reliability. The staff requires the M-MIS to meet the requirements of Section 5.3 of IEEE 603 for reliability goals. The staff concluded that this section should be clarified to reflect this position and identified the overall reliability of the M-MIS as an open issue. In its response dated

January 28, 1992, EPRI stated that the determination of component reliability data called for in Section 3.5.4.1 and the reliability tests apply to hardware components only. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will evaluate this item during its review of an individual application for FDA/DC.

Section 3.5.4.2 of Chapter 10 specifies that the designer will perform analyses of all hardware and software to identify unplanned operational modes. This section refers to MIL-HDBK-338 as general guidance. In the rationale, EPRI defines a sneak circuit as a latent condition in a system that may result in unexpected operation that is not due to equipment failure but rather to design oversight. The sneak circuit analysis (SCA) is a method for reducing these design errors. EPRI states that because of the complexity and size of many of the systems in the M-MIS, system testing to identify the sneak circuits is not an economical or logistically feasible alternative. It also notes that sneak circuits can appear in mature, thoroughly tested systems even after long periods of field use. In the DSER for Chapter 10, the staff concluded that SCA could be a useful tool; therefore, an across-the-board elimination of system testing was unacceptable. It identified SCA as an open issue. In its response dated January 28, 1992, EPRI stated that the Evolutionary Requirements Document requires both system testing and SCA. This response clarifies EPRI's intent that SCA is not expected to be a substitute for system testing and is acceptable. This DSER open issue is closed.

Section 3.5.4.3 of Chapter 10 requires the designer to perform failure modes and effects analyses consistent with the guidance of MIL-HDBK-338 and MIL-STD-1629A, "Procedures for Performing a Failure Modes Effects and Criticality Analysis." This analysis will be used to demonstrate that the M-MIS meets the quantitative reliability and maintainability goals. The staff concludes that this is acceptable, but notes that the requirements of IEEE 603 (which includes the requirements of IEEE 577 and 352) also apply.

Section 3.5.4.4 of Chapter 10 states that the designer will perform analyses of the M-MIS hardware to predict the amount of time that a system or component will be inoperative because of maintenance. The guideline to be used is MIL-HDBK-472, "Maintainability Prediction." The results will be used to determine if the goals of Section 3.7 of this chapter of the Evolutionary Requirements Document have been met. The staff concludes that this is acceptable.

3.6 <u>Testability Requirements</u>

3.6.1 Continuous On-Line Testing

Section 3.6.1 of Chapter 10 of the Evolutionary Requirements Document states that the capability for continuous on-line testing of hardware integrity will be provided when practicable. These tests may include random access memory and read-only memory failure checks, arithmetic processing unit failure checks, data link buffer checks, and central processing unit reset of watchdog timers. In the DSER for Chapter 10, the staff concluded that the rationale had to be clarified as to whether the tests listed were the minimum tests to meet technical specifications or other regulatory requirements and identified minimum tests for continuous on-line testing as an open issue. In its response dated January 28, 1992, EPRI stated that this section requires that a continuous on-line self-testing capability be provided for as much of the M-MIS as is practicable. EPRI also stated that the continuous on-line self-test can be used to satisfy the testing requirements of the technical specifications and regulatory requirements where practicable. The staff concludes that the requirement for continuous self-diagnostics is good engineering practice and is, therefore, acceptable. Therefore, this DSER open issue is closed. However, the staff will evaluate the specific method used for meeting a specific technical specification during its review of an individual application for FDA/DC.

3.6.2 Periodic Testing

Section 3.6.2 of Chapter 10 states that capability for periodic testing will be provided and will meet Regulatory Guides 1.22, "Periodic Testing of Protection System Actuation Functions," and 1.118, "Periodic Testing of Electric Power and Protection Systems," and IEEE 338. The testing will be manually initiated but automatically performed. Automatic initiation of testing is allowed where it can be shown that it does not affect system function. The staff is not aware of any instances where these features proved to be undesirable; therefore, this requirement is acceptable. This type of test capability also will reduce the likelihood of transients initiated by human error.

3.6.3 Reliability of Testing Features

Section 3.6.3 of Chapter 10 states that the mean time between failures of the M-MIS continuous on-line self-test features and periodic functional test features will be equal to or greater than that of the equipment they are testing. The staff concludes that this requirement is acceptable. The failure of the testing features also should have no effect on the tested system.

3.6.4 Reconfiguration After Failure Detection

Section 3.6.4 of Chapter 10 states that the M-MIS is to be designed so that, if a failure is detected in the system, the M-MIS will automatically reconfigure so that an additional single failure will not prevent system-level protection or safety action. The staff agrees with the concept of additional failure protection. However, it will evaluate the details of the automatic reconfiguration setup during its review of an individual application for FDA/DC. In its request for additional information dated April 10, 1990, the staff asked if this requirement would allow a safety channel to be automatically bypassed and if operator notification was via the non-safety annunciators. By letter dated July 23, 1990, EPRI stated that the configuration would not bypass the channel in the sense of preventing a trip - rather, it would set up the remainder of the system so that a protection trip would occur when needed, even if a second failure should occur. In addition, EPRI responded that although non-safety annunciation should be acceptable, annunciation of the bypass via the operator workstations would be via safety-grade equipment. The staff concludes that the requirements of this section of the Evolutionary Requirements Document are acceptable.

3.6.5 Failure Location Identification

Section 3.6.5 of Chapter 10 states that the test features will identify the location of the detected failure down to the lowest replaceable module. The staff agrees with this requirement.

3.6.6 Classification of Automatic Test Circuits

Section 3.6.6 of Chapter 10 states that the automatic testers will be classified as associated Class 1E as described in IEEE 384. IEEE 384-1981 gives criteria for the independence that can be achieved by physical separation and electrical isolation. This standard does not address software-based systems, and the staff has stated that the software-based on-board diagnostics and automatic testers need to be qualified as Class 1E. Section 5.5.3 of IEEE 384 states that associated circuits need not be qualified for performance of function. The staff concludes that these automatic test circuits are being used to verify the correctness of the safety-grade hardware and software that cannot otherwise be verified and therefore are required to be the same classification. IEEE 384 requires the associated circuit to be the same quality as the Class 1E circuit and, for software, that would mean use of the same verification and validation procedures. In its letter of July 23, 1990, EPRI stated that it would add a new requirement, Section 6.1.5.10, to Chapter 10 to require that all software and firmware used to meet the testability requirements in this section be of a level comparable to that of the base program software. In the DSER for Chapter 10, the staff identified this as a confirmatory issue. The staff has verified that EPRI has modified Section 6.1.5.10. Therefore, this DSER confirmatory issue is closed.

3.6.7 System Reconfiguration for Testing

Section 3.6.7 of Chapter 10 states that built-in, manually initiated, automatically performed test features will be installed to eliminate the jumpers and lifted leads of previous designs. The staff considers this to be a significant improvement over current operating plants and concludes that this requirement is acceptable.

3.6.8 Safety-Related System Testing

Section 3.6.8 of Chapter 10 states that the automatic testing features for the safety-related systems will be sufficient to meet the technical specification requirements for periodic surveillance as defined by Regulatory Guides 1.22 and 1.118 and IEEE 338. The methods used to meet technical specification requirements will be established for specific designs. Therefore, the staff will evaluate the adequacy of the surveillance period of these testing features during its review of an individual application for FDA/DC.

3.6.9 Test Performance

Section 3.6.9 of Chapter 10 states that, as much as possible, the test features of the M-MIS will be designed so that the tests can be performed when the plant is at power. The staff agrees that test features should be incorporated into the design; therefore, this is acceptable.

3.6.10 Automatic Bypass

Section 3.6.10 of Chapter 10 states that when a test is initiated manually, the correct bypasses will be established automatically. Regulatory Guide 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems," states (in the discussion section) that, generally, the plant's administrative procedures require that the operator's permission be obtained before any activity that would or could affect a safety-related system is initiated. The decision to grant such permission should be based on a knowledge of the operating status of the safety-related systems, the extent to which the activity will affect those systems, and whether the action is permissible within the provisions of the license. The regulatory guide lists the need for automatic indication of any bypass or inoperable status. It does not address automatic initiation of the bypass. Because this EPRI requirement does not violate the NRC criteria, it is acceptable. However, the staff will evaluate the level of implementation during its review of an individual application for FDA/DC to ensure that the operators are aware of all automatic bypasses for each test initiated.

In its request for additional information dated April 10, 1990, the staff noted that in the rationale for this requirement, EPRI did not discuss the tradeoffs between operator error and potential increased software error. By letter dated July 23, 1990, EPRI stated that preliminary evaluations have led to the conclusion that the use of automatic testing improves plant reliability. The staff concludes that the requirements of this section are acceptable.

3.6.11 Indicators for Test and Bypass Status

Section 3.6.11 of Chapter 10 states that local indication of pass or fail for the test and bypass status will be provided. Although not referenced here by EPRI, the staff concludes that the requirements of Regulatory Guide 1.47 will be applied to this indication.

3.6.12 Test Result Records

Section 3.6.12 of Chapter 10 states that a printer interface will be provided at the test cabinet to allow the operators to obtain a hard copy of the test results. The staff has no reason to believe that providing this feature as a convenience to the operators will have an adverse effect on plant operations or safety. Therefore, this feature is acceptable.

3.6.13 Removal of Automatic Bypass

Section 3.6.13 of Chapter 10 states that the bypasses will be automatically removed when testing is complete. Indication will be provided for the operators to verify bypass status. The staff concludes that this requirement is acceptable and will evaluate the acceptability of its implementation as part of its evaluation of automatic bypass initiation during its review of an individual application for FDA/DC.

3.6.14 Process Input Signals

Section 3.6.14 of Chapter 10 states that the safety system processors are required to remain in their normal execution paths and, therefore, automatic testing will be performed using simulated process input signals. However, EPRI has not demonstrated that simulated inputs provide an accurate test for all real conditions. The staff will need to see specific implementation information before it can find this method acceptable. It will evaluate the acceptability of this information as part of its evaluation of automatic bypass initiation during its review of an individual application for FDA/DC.

3.6.15 Testing at Initialization of Processors

Section 3.6.15 of Chapter 10 states that comprehensive self-diagnostic routines will be performed on initialization of all processors. In its request for additional information dated April 10, 1990, the staff asked EPRI to evaluate the effects of a time delay following postulated M-MIS failures. By letter dated July 23, 1990, EPRI responded that any additional time required to get the system on line and operational will be considered in the requirements pertaining to mean time to repair. The staff concludes that this is acceptable.

3.7 <u>Maintainability</u>

Section 3.7 of Chapter 10 states that the M-MIS is to be designed for simplification of maintenance over the lifetime of the plant. The staff agrees with the increased emphasis on maintenance concerns during the design phase.

3.7.1 Maintenance Burden

Section 3.7.1 of Chapter 10 states that the impact of maintenance activities on the operator and maintenance personnel will be quantified.

3.7.2 Replacement of Equipment

Section 3.7.2 of Chapter 10 states that service life and replacement needs will be considered in the design.

3.7.3 Modular Replacement

Section 3.7.3 of Chapter 10 states that the M-MIS is to be designed so that normal repair activities will consist of simple module replacement in the field and repair of the module in the shop.

3.7.4 Time To Detect and Repair a Failure

Section 3.7.4 of Chapter 10 states that the time to detect and replace a faulty module will be less than 4 hours average with a maximum of 8 hours for any single module. This requirement is only required for equipment with self-test capabilities or where possible. Any specific technical specifications would still have to be met. The staff notes that this requirement applies only for those failures that can be repaired by replacing the module. In its request for additional information dated April 10, 1990, the staff asked how these requirements pertain to reliability and how the detection of software errors and the correction of errors are considered. By letter dated July 23, 1990, EPRI responded that this section does not address correction of software errors. EPRI considers those to be design errors that are addressed via the verification and validation process. The staff concludes that module software concerns and out-of-service time can be addressed in technical specification requirements for specific designs; therefore, this requirement is acceptable. The staff will address the technical specification issue during its review of an individual application for FDA/DC.

3.7.5 On-Line Calibration

Section 3.7.5 of Chapter 10 states that any module that requires calibration more often than during each scheduled refueling outage will be capable of being calibrated on line while maintaining control, monitoring, and system performance requirements.

3.7.6 On-Line Maintenance and Repair

Section 3.7.6 of Chapter 10 states that expected maintenance or repair will not prevent any system from fulfilling its requirements. On-line repair is preferred. The staff will evaluate bypass and test lockouts for the channel that is not in repair during its review of an individual application for FDA/DC.

3.7.7 Maintenance Human Factors

Section 3.7.7 of Chapter 10 states that human factors with regard to maintenance will be considered in the M-MIS design. The human factors issues are evaluated by the staff in Appendix D of this chapter.

EPRI states that the designer will identify the maintenance tasks as part of the design and will evaluate these tasks to ensure that they are simple and well understood. Equipment will be labeled in accordance with the general guidance of EPRI NP-6209, "Effective Plant Labeling and Coding." In general, the equipment will be designed to facilitate maintenance activities. Access for maintenance personnel will be considered during the design process.

Section 3.7.7 of Chapter 10 further states that maintenance activities will be designed so that they do not interrupt the operator at manned control stations. The M-MIS equipment will be designed to facilitate testing and repairs without requiring the operator to assist. The operators will be provided with indication that testing or repairs are being performed. Controls and displays used only by maintenance personnel will not be located on panel fronts unless they are covered and do not crowd the operator's controls.

3.8 <u>Constructibility</u>

Section 3.8 of Chapter 10 of the Evolutionary Requirements Document specifies that features will be included in the M-MIS design to reduce construction time and effort.

3.8.1 Use of Proven Techniques

Section 3.8.1 of Chapter 10 states that proven manufacturing, assembly, and installation techniques will be used for the fabrication and installation of M-MIS equipment.

3.8.2 Minimization of Field Operations

Section 3.8.2.1 of Chapter 10 states that the M-MIS will be designed to facilitate installation. Each module will allow installation and functional testing before integration of the complete system. Shop fabrication of modules will be used where possible, and the amount of field wiring will be minimized.

Section 3.8.2.3 of Chapter 10 states that spare conductors will be provided in wire harnesses and cables where practicable. In the rationale, EPRI states that the spare conductors could be used to replace wiring damaged during the shipping or installation of equipment. In its request for additional information dated April 10, 1990, the staff stated that the use of spare conductors might violate the factory acceptance testing described in Section 3.8.2.2 of Chapter 10 of the Evolutionary Requirements Document. The staff considered the inclusion of spares for possible future modifications to be a good design practice but was concerned about the rationale provided for installing damaged equipment. By letter dated July 23, 1990, EPRI clarified that its intent is to provide spare conductors for future modifications.

In the DSER for Chapter 10, the staff identified the installation of spare cable conductors as a confirmatory issue. The staff has verified that EPRI has revised Section 3.8.2.3 to note that damaged multiconductor cable would normally require complete replacement; therefore, this DSER confirmatory issue is closed.

3.8.3 Standardized Designs for Construction

Section 3.8.3 of Chapter 10 states that the equipment used in construction such as connectors and labels will be standardized as much as possible.

3.8.4 Schedule for Construction

Section 3.8.4 of Chapter 10 states that the construction, fabrication, and installation of the M-MIS will support the overall plant construction schedule.

3.9 Design Flexibility

Section 3.9 of Chapter 10 of the Evolutionary Requirements Document states that the design will provide flexibility for changes or replacement by including spare capacities and modular design.

3.10 Conclusion

The staff concludes that the requirements in Section 3 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

4 CONTROL STATION REQUIREMENTS

4.1 Control Station Design Process Requirements

Section 4.1 of Chapter 10 of the Evolutionary Requirements Document indicates that the M-MIS design will be consistent throughout the plant. The staff's evaluation of the human factors aspects of this section is provided in Appendix D of this chapter.

4.1.1 Utilization of Functions and Tasks

Section 4.1.1 of Chapter 10 states that the control station will be designed on the basis of the overall identification of functions and tasks listed in Section 3.1.3.3 of Chapter 10 of the Evolutionary Requirements Document.

4.1.2 Control Station Conceptual Designs

Section 4.1.2 of Chapter 10 states that, following the initial definition of tasks, the designer will prepare a conceptual design for each control station. This conceptual design will include a layout drawing of the station, identification of the major control and display characteristics, a specific listing of tasks in sequence, requirements for information and control, and preliminary procedures for control station operation.

4.1.3 Review of Conceptual Designs

Section 4.1.3 of Chapter 10 states that the interdisciplinary design group will review each control station conceptual design. The control station review team will include human factors and operation specialists in addition to the traditional engineering disciplines involved in the equipment design. A static mockup of each control station will be used in the design process. The design process will provide for the use of active simulation of the control stations. In the DSER for Chapter 10, the staff stated that this requirement, however, did not provide any guidance on when simulators were necessary or when mockups were adequate. The staff concluded that EPRI should provide such guidance and identified guidance on the use of simulator and mockups as an open issue. In its response dated January 28, 1992, EPRI stated that the intent of this requirement is to require mockups for all control room panels and simulation for the main control room (MCR) and the remote shutdown station, as a minimum. EPRI also stated that the requirement requires the design process to identify any special workstation outside the MCR with a unique need for simulation. This is acceptable because it does not conflict with current regulatory guidance. However, this requirement still does not provide clear guidance on when simulators are necessary or when mockups are adequate. The staff will evaluate this item during its review of an individual application for FDA/DC. Therefore, this DSER open issue is closed.

The staff's evaluation of the human factors aspects of this section are contained in Appendix D of this chapter.

4.1.4 Iteration of Functions, Tasks, and Designs

Section 4.1.4 of Chapter 10 states that the design process will provide for feedback, from the control station design to the original overall identification of functions and tasks, to correct any unsatisfactory control station designs. The staff concludes that this is good engineering practice and is acceptable. The staff's evaluation of the human factors aspects of this section is provided in Appendix D of this chapter.

4.1.5 Definition of Design Practices

Section 4.1.5 of Chapter 10 states that the design will follow the guidance on human factors practice, such as that in EPRI NP-3659, "Human Factors Guide for Nuclear Power Plant Control Room Development," and EPRI NP-6209, "Effective Plant Labeling and Coding " These guidelines address the subjects that are to be considered during the design process but leave the details and selections to the designer. When the designer selects new technology for which published human factors guidance is limited, EPRI states that the designer will develop the necessary design practices based on the best available information. These design practices will be verified by experimentation and simulation. The staff finds that this requirement is vague and appears to contradict the EPRI requirement to use proven technology. As do many of the requirements in the Evolutionary Requirements Document, this one will allow many designs or technologies. However, this requirement is acceptable because it does not conflict with current regulatory requirements. The staff's evaluation of the human factors aspects of this section is contained in Appendix D of this chapter.

4.1.6 Documentation of Final Designs

Section 4.1.6 of Chapter 10 specifies that the final design of the control stations will be documented in detail. The staff concludes that this is a good design practice.

The design configuration will be presented in a format useful to the operators. The design documentation for each control station will define the functions and tasks for that station. EPRI states that the design documentation also will define the common design practices used for all stations and will document any differences for a specific station. It will also include the generic operating procedures. Appendix D of this chapter contains the staff's evaluation of the human factors aspects of generic operating procedures.

4.2 <u>Operating Crew</u>

Section 4.2.1 of Chapter 10 of the Evolutionary Requirements Document indicates that the M-MIS design will accommodate the normal shift staffing and the emergency operations staffing, including supervisory personnel and NRC observers. The designer will specify the responsibilities to be assumed by operating crew members so that the utility can plan staffing and training. The staff's evaluation of the human factors aspects of this section is contained in Appendix D of this chapter.

In its request for additional information dated April 10, 1990, the staff asked EPRI to address the staffing requirements for maintenance personnel because the mean time-to-repair estimates were relatively short for complex equipment. By letter dated July 23, 1990, EPRI responded that the specific maintenance personnel requirements will not be defined until experience with the new technology is gained. The staff concludes that maintenance staff requirements should be developed during the testing and validation of newer designs. Since the technical specifications will address the time that a system can be out of service rather than a required maintenance staffing level, this requirement is acceptable.

Section 4.2.2 of Chapter 10 provides a list of assumptions regarding operator staffing during emergencies that are to be used in performing the analyses required by EPRI in Section 3.1.3.3.2 of Chapter 10 of the Evolutionary Requirements Document. The staff concludes that these assumptions are consistent with current regulatory requirements for licensed operators and are acceptable.

Section 4.2.2.2 of Chapter 10 originally required that the time for an operator to react in an emergency be less than 20 minutes. However, the design would not prevent the operator from taking action before 20 minutes. In its request for additional information dated April 10, 1990, the staff asked EPRI to address manual scram and the use of a longer time limit. By letter dated July 23, 1990, EPRI responded that the time requirement would be changed to 30 minutes, including manual scram. In Revision 4 to the Evolutionary Requirements Document, EPRI changed the time requirement for an operator to react in a emergency to not less than 30 minutes.

In Sections 4.2.2, 8.2.3, and B.6 of the DSER for Chapter 10, the staff identified operator action emergency timing as a confirmatory issue. The staff has verified that EPRI has modified Section 2.3.3.5 and Table 1.2-5 of Chapter 1 and Section 4.2.2.2 of Chapter 10 to require not less than 30 minutes for an operator to react in an emergency. The 30-minute response time is provided through plant characteristics, such as large steam generator and pressurizer inventories and reactor coolant system pressure control and heat removal, which will enable the reactor and other systems to meet challenges without operators being required to take action within the first 30 minutes. Therefore, this DSER confirmatory issue is closed.

Section 4.2.3 of Chapter 10 specifies that the main control room (MCR) will support a maximum of eight crew members with provisions made for three active observers, one from the NRC, one from the plant owners management, and one to handle communications during emergencies. However, current agency procedures (NUREG-0845, Agency Procedures for the NRC Incident Response Plan and Information Notice (IN) 86-18, "NRC On-Scene Response During A Major Emergency") indicate that one NRC observer will initially report to the control room in an emergency (or technical support center (TSC) if activated) and that two NRC observers (and possibly a third person) will be located in the control room as part of an expanded site team. This was identified as an open issue in DSER for Chapter 10. In its response dated January 28, 1992, EPRI stated that a more effective location for the second NRC observer might be the TSC because of the EPRI requirements that TSC personnel have access to all the monitoring data available to the control room operators and that they be able to visually monitor activities in the MCR (either by direct viewing or closed-circuit TV). EPRI further stated that the specific work areas for the observers in the MCR will allow for temporary occupancy by two persons when the personnel are being relieved. The staff finds that the EPRI concept for accommodating an expanded NRC site team in the event of an emergency is acceptable. Therefore, this DSER open issue is closed.

However, recent operating experience (IN 91-77, Shift Staffing at Nuclear Power Plants) has indicated that during emergencies it may be necessary for the licensee to expand its shift staffing beyond that indicated by EPRI in Section 4.2.3 of Chapter 10. EPRI should retain the flexibility to accommodate additional staffing in the MCR in the event of an emergency. The staff will review individual applications for FDA/DC to ensure that sufficient space has been provided in the MCR to adequately respond to all events.

Section 4.2.4 of Chapter 10 states that the M-MIS will be designed so that a single operator can accomplish all normal functions, including taking the plant from hot standby to full power and back again. In the rationale, EPRI states that it is not its intent that this requirement be in noncompliance with current regulatory requirements regarding the number of licensed operators required for plant startup. EPRI expects that if operations can be performed under normal, routine circumstances by a single individual, the additional personnel who will actually be available will be free to handle upsets and emergencies. The minimum number of licensed operators required to be on shift and on site is specified in 10 CFR 50.54(m). In addition, the staff's position on the selection, qualification, and testing of operating plant personnel is given in Appendix D of this chapter.

Section 4.2.5 of Chapter 10 states that the M-MIS will be designed so that the normal shift crew can start up and shut down the plant. Operators at local control stations are still expected for these operations.

Section 4.2.6 of Chapter 10 states that the design will be based on the operator skill levels at existing plants when practicable or the designer will specify any differences in these levels.

4.3 Alarms

Annunciators are also discussed by the staff in Appendix D of this chapter.

4.3.1 General Alarm System Requirements

Section 4.3.1 of Chapter 10 states that the M-MIS will include a main process alarm system and local alarm systems. The alarm systems will alert the operators to off-normal conditions and assist them in determining the state of the plant. Emphasis will be placed on minimizing distraction and unnecessary workload. EPRI states that the design will follow the guidance of EPRI NP-3448, "A Procedure for Reviewing and Improving Power Plant Alarm Systems," and EPRI NP-3659.

The function and task analysis will specifically address alarm information. The alarm system will be testable to verify its operating status. The effectiveness of the alarm system will be verified with a real-time, dynamic simulator. The designer will define the measures used to judge the effectiveness of the alarm system early in the design process. Recent operational experience has shown a vulnerability in the power supplies for the alarm system. Therefore, in the DSER for Chapter 10, the staff concluded that EPRI should reevaluate the design basis for and the reliability of power supplies for the alarm system and identified vulnerability of these power supplies as an open issue. In its response dated January 28, 1992, EPRI stated that even though the Evolutionary Requirements Document does not include the power supply requirements unique to the alarm system, it requires the alarm system to cope with the potential failures as discussed in Section 3.1.3.4 of Chapter 10 and to accommodate the single failures in the M-MIS without a resulting forced outage. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff's concerns about the reliability of the alarm systems extend beyond not causing a forced outage; therefore, the staff will evaluate this issue during its review of an individual application for FDA/DC.

4.3.2 Selection of Alarm Conditions

Section 4.3.2 of Chapter 10 indicates that a consistent approach will be used in selecting plant conditions that are to be alarmed. The staff concludes that this is a good engineering practice and is acceptable.

The alarms will be presented in a "dark board at power" format; that is, no alarms should be present when the plant is operating normally at full power with all systems in their normal configuration. The Evolutionary Requirements Document references EPRI NP-3448 for guidance. In its request for additional information dated April 10, 1990, the staff asked EPRI to describe the method that would be used to verify operability of the dark-board alarms. In its letter of July 23, 1990, EPRI responded that the method would be similar to the current method, that is, primarily periodic testing. The staff concludes that this is consistent with current regulatory practice and is acceptable.

EPRI states that the designer will outline a response procedure for each alarm condition. The operator will be provided the capability to establish temporary alarms and setpoints for specific conditions. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide additional justification for this requirement. Although the staff encourages operator input during the design, it concludes that operator manipulation of software, alarms, and setpoints during plant operation needs to be evaluated in detail. By letter dated July 23, 1990, EPRI stated that this requirement is limited to providing the capability for additional operator-defined alarms to monitor special, temporary situations without affecting the required alarms. The staff concludes that this requirement does not conflict with current regulatory requirements and is acceptable.

EPRI states that the designer will document the basis for each alarm selection and will follow the guidance in EPRI NP-3448.

4.3.3 Alarm Processing

Section 4.3.3 of Chapter 10 states that the alarm system will be designed to minimize the potential for nuisance alarms and to allow time filtering or delays and conditioning of the input signals. EPRI states that the designer will evaluate individual alarms to examine the potential for nuisance alarming. The following will be considered in the evaluation:

- all modes of operation
- maintenance of the associated system or equipment
- possible momentary alarms
- allowable system transients
- alarm input noise
- unusual system lineups
- other conditions

EPRI states that the designer will select the alarm setpoint, delays, conditioning logic, and other features on the basis of the evaluation of the criteria listed above. In its request for additional information dated April 10, 1990, the staff asked EPRI to address the tradeoffs between nuisance alarms and the added complexity of the system and the possibilities of not getting the alarm when warranted. By letter dated July 2[illegible], 1990, EPRI responded that it would revise this section to add a requirement that the elimination of the nuisance alarms specifically not prevent alarms when warranted.

In the DSER for Chapter 10, the staff identified elimination of nuisance alarms as a confirmatory issue. The staff has verified that EPRI has modified the Evolutionary Requirements Document as stated above. Therefore, this DSER confirmatory issue is closed.

EPRI indicates that an alarm that has more than one input will have the capability to actuate again if an alarm condition occurs after a first alarm has occurred and been acknowledged. The staff concludes that this is a desirable feature and is acceptable.

The Evolutionary Requirements Document states that the alarm system will be designed to minimize the number and rate of alarms during plant upsets. The primary method will be the use of component- and system-based logic to make the alarms less likely to occur unnecessarily. Alarm suppression schemes are allowed if justified by the designer. The staff concludes that this requirement is acceptable. However, it will evaluate the methods to be used and the details of the suppression schemes during its review of an individual application for FDA/DC.

4.3.4 Alarm Presentation

Section 4.3.4 of Chapter 10 provides requirements to ensure that alarm information will be presented so that both individual and crew needs are supported. The alarms will be integrated with the controls and displays for ease of use by the operator.

The alarms that require a short response time by the operator will be spatially dedicated, continuous, and located with the controls and displays for the function that is alarmed. Both the normal and alarm state will be presented. The alarms are to be grouped by system or function. EPRI indicates that the designer should use the guidance in EPRI NP-5693 and NP-3448. Alarms will be prioritized, and the priorities will be established on the basis of criteria that will be part of the design practices. In the DSER for Chapter 10, the staff concluded that this requirement did not conflict with current regulatory requirements and was acceptable. However, it did not provide any criteria for the assignment of priorities. The staff concluded that EPRI should provide such guidance and identified guidance on criteria to establish alarm priorities as an open issue. In its response dated January 28, 1992, EPRI stated that prioritization of alarms will be based on relative importance or urgency and the time within which the operator must take action. EPRI also stated that the detailed definition of prioritization would pre-empt the design process and would be unlikely to result in a well-balanced and integrated alarm system. This is acceptable because it does not conflict with current regulatory requirements. Therefore, this DSER open issue is closed. However, the staff will evaluate this issue during its review of an individual application for FDA/DC.

The number of alarms assigned the highest priority will be limited. In the DSER for Chapter 10, the staff concluded that this requirement was acceptable, but there was no specific guidance as to the maximum limit that would be considered acceptable. The staff concluded that EPRI should provide such guidance and identified guidance on the maximum number of alarms as an open issue. In its response dated January 28, 1992, EPRI stated that setting a single quantitative limit on the number of high-priority alarms will be defined in detail as part of the design process. This is acceptable because it does not conflict with current regulatory requirements. Therefore, this DSER open issue is closed. However, the staff will evaluate this item during its review of an individual application for FDA/DC.

The display capacity used for the alarms will not be exceeded during accident situations, and paging of the display will not be required to view all of the highest priority alarms. The prioritization will be evaluated using real-time simulation.

EPRI states that the alarm system controls will be located so that the operator can respond adequately and so that they can be read by the operator from the control station being used to respond to the alarm. The alarm system will have different tone capability so that the operator will be able to tell from the tone and the direction of the sound what the priority and general system involved are without looking. The alarms will be treated as an integral part of the design.

Section 4.3.4 of Chapter 10 states that each alarm will be tagged to a resolution of 2 seconds or less. Points that are specifically designated as sequence-of-events alarms will have a resolution of 4 milliseconds or less, unless the designer demonstrates a longer time resolution is acceptable.

At least 4 hours of recorded alarm sequence will be provided. The time sequence of alarms will be kept as a permanent record of plant operation. In the DSER for Chapter 10, the staff concluded that this requirement was acceptable as long as a method is provided to make copies of the alarm sequence so that a continuous alarm sequence will be available for events exceeding 4 hours and identified alarm sequence recording as an open issue. In its response dated January 28, 1992, EPRI stated that the intent of this section is to ensure that the MCR operators have immediate access to a detailed time sequence of alarms at their workstations to support their actions. In addition, the purpose of this alarm record is to help the operators understand events leading up to and causing an upset. Maintaining a complete historical record of all alarms in the aftermath of a major accident, however, is not the purpose of this alarm record. EPRI also stated that the existing provisions of the Evolutionary Requirements Document require a complete record of alarms (greater than 4 hours) and a capability for retention and later access. This recording is beyond the currently required recording and, therefore, is acceptable. This DSER open issue is closed.

4.4 Displays

Section 4.4 of Chapter 10 of the Evolutionary Requirements Document specifies that the displays will be designed using the guidance of EPRI NP-3659 and NP-3701, "Computer-Generated Display Guidelines" (Volumes 1 and 2). In its request for additional information dated April 10, 1990, the staff asked EPRI to address how the display requirements of Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants To Assess Plant and Environs Conditions During and Following an Accident," will be implemented. By letter dated July 23, 1990, EPRI responded that the requirements will be met with the normal qualified instrumentation. Some items will be on the overview panel in addition to the workstations. EPRI stated that it would revise Section 4.9.1.8 of Chapter 10 to require that postaccident monitoring to be accomplished with normal plant instrumentation.

In the DSER for Chapter 10, the staff identified instrumentation for post-accident monitoring as a confirmatory issue. The staff has verified that EPRI has revised Section 4.9.1.8 as stated above. Therefore, this DSER confirmatory issue is closed.

Section 4.4.1 of Chapter 10 indicates that the number of different types of displays will be minimized.

Section 4.4.2 of Chapter 10 states that position or status information will be provided directly rather than through the demand signal. The staff concludes that this is a generally desirable feature and is acceptable.

Section 4.4.3 of Chapter 10 indicates that displays will clearly indicate loss of functionality. Loss of power to a meter will not result in failing to midscale, which could be interpreted by the operator as a valid signal.

Section 4.4.4 of Chapter 10 states that indication for valves will be provided at the control location and other places as needed. Continuous indication will be provided for throttling valves. In Section 6.2.7 and Appendix D of this chapter, the staff discusses further the requirements for valve indication.

Section 4.4.5 of Chapter 10 states that indication of current draw will be provided for any major motor that can be started from the control station. The indication will identify the normal starting and running current draw. This does not apply to motors that operate briefly.

Section 4.4.6 of Chapter 10 states that indicator lights that use a single light element such as incandescent bulbs and light-emitting diodes will not be used.

Section 4.4.7 of Chapter 10 states that conventional paper-and-ink strip chart recorders will not be used. The data recording function of the recorders will be provided by the plant data system.

Section 4.4.8 of Chapter 10 states that the designer will evaluate the need for coordinating the tasks of multiple workstations when the stations are located in the same room. Displays will be included in the design process. The main control room will include a display that will provide the values of key operating parameters, including power level, high pressure, temperature, and flow rate indication, and the operational status of essential components that are controlled or monitored from the control room.

Section 4.4.10 of Chapter 10 specifies that closed-circuit television will be used for areas that are not easily accessible to the operators because of the need to keep radiation exposure of personnel as low as is reasonably achievable or other considerations. This is acceptable.

The staff's evaluation of the human factors aspects of this Section 4.4 of Chapter 10, is contained in Appendix D of this chapter.

4.5 Contiols

Section 4.5 of Chapter 10 of the Evolutionary Requirements Document requires the designer to develop specifications for the M-MIS that are consistent with the guidance of EPRI NP-3659. As noted in the rationale, this guidance does not prescribe the design details but rather identifies the attributes that have to be considered by the designer.

Section 4.5.1 of Chapter 10 states that the M-MIS design will minimize the number of different types of controls as much as possible.

EPRI requires that each control identify the power source of the controlled device. However, Section 4.5.2 of Chapter 10 does not give any specific method for accomplishing this task.

Section 4.5.3 of Chapter 10 specifies that the normal control position will be identified consistently.

Section 4.5.4 of Chapter 10 requires that measures other than locked controls be used to prevent the inadvertent actuation of controls and that key-locked controls not be used for controls that may need to be actuated in response to an emergency. The staff concludes that this requirement is intended for plant safety and process controls and is not applicable to key-locked controls that may be necessary for single-insider protection in the design of security alarm station consoles. The requirements of Section 4.5 of Chapter 10 specify desirable attributes for controls and are acceptable.

The staff's evaluation of the human factors aspects of Section 4.5 of Chapter 10 is contained in Appendix D of this chapter.

4.6 Voice ..mmunication Systems

Section 4.6.1 of Chapter 10 of the Evolutionary Requirements Document states that the scope of Section 4.6 includes both in-plant communications for operations and maintenance and communications outside the plant, such as communication with a load dispatcher as well as with agencies with which communication is needed to support emergency operations. Requirements for specific security system communications are included in Chapter 9 of the

Evolutionary Requirements Document. The staff agrees that the general communication requirements of Chapter 10 are also applicable to security communication systems, as clarified in EPRI's letter dated October 12, 1990.

Section 4.6.2 of Chapter 10 states that the primary, dedicated means of communication between operators during normal or emergency operation will be by portable, wireless communication equipment supported by appropriate base stations, antennas, amplifiers, and/or repeaters. A plant-wide paging system will be included. Dedicated phone links primarily will be used for offsite communications. The staff notes that extensive wireless communication will increase the emphasis on consideration of electromagnetic interference (EMI) in the design of the M-MIS. However, the use of this type of communication system is not specifically excluded in NRC regulations and may be necessary to meet the requirements of 10 CFR Part 73; therefore, it is acceptable.

This section, in addition to identifying areas for the designer to evaluate, specifies the communication designer will develop a frequency allocation plan to ensure that there is no interference between communication systems and to ensure compatibility with the EMI/radiofrequency interference (RFI) measures taken by the electronic and computer designers. In the DSER for Chapter 10, the staff concluded that this was a good engineering goal and was acceptable. However, no specific guidance on methods to achieve this goal was provided. The staff concluded that EPRI should provide such guidance and identified guidance on a frequency allocation plan as an open issue. In its response dated January 28, 1992, EPRI stated that the allocation of frequencies requires detailed technical information that depends highly on the specific plant and equipment design. EPRI also stated that it is not practical to provide specific guidance or requirements on the frequency allocation plan itself. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. The staff, however, will evaluate this item during its review of an individual application for FDA/DC.

Section 4.6.2.2 of Chapter 10 requires the designer of the communication system to include an analysis of the specific communication needs and the specific design requirements in the design-basis documentation. Additional communication needs for security operations are addressed in Chapter 9 of the Evolutionary Requirements Document and the interface with Chapter 10 noted therein. Requirements for security communications also are specified in 10 CFR 73.55(f).

Section 4.6.3 of Chapter 10 indicates that the method preferred by EPRI for dedicated wireless communications is a point-to-point method similar to cellular telephones in which each receiver can be specifically addressed. The capability to have open multiparty communication will exist. Adequate equipment is to be provided to ensure clear communications.

EPRI states that potential high-noise areas will be considered in the communication system design and the plant designer will provide adequate means to alert personnel in high-noise environments to use the communication systems.

The design of portable communication equipment will be integrated with the design of protective equipment, including diving suits and respirators, so that personnel wearing this protective equipment will be able to communicate effectively. EPRI states that the design will apply the guidance developed by

EPRI on voice communication systems that are compatible with respiratory protection (EPRI NP-6559). The staff concludes that this is good design practice and is acceptable.

Section 4.6.3 of Chapter 10 states that an ample (unspecified) number of communication channels will be provided. This section stipulates that there will be no interference between the communication systems and M-MIS equipment. The communication designers are required to define the worst-case emissions from the communication equipment, including the type, magnitude, frequency content, and locations. All potential uses of the communication gear will be considered. EPRI states that adequate protection will be provided for the M-MIS equipment. Maintenance activities will be considered. The communication system also will be protected from the M-MIS equipment to the extent that clear communications are maintained. In the DSER for Chapter 10, the staff agreed with this goal and concluded that it was acceptable. However, because of the potential effects of EMI/RFI on the M-MIS equipment, the staff concluded that EPRI should provide design guidance regarding implementation of this goal and identified guidance on interference between communication systems and M-MIS equipment as an open issue. In its response dated January 28, 1992, EPRI stated that the Evolutionary Requirement Document requires the designer to design the communication equipment and all M-MIS electronic equipment so that there will be no interference between the communication system and the M-MIS equipment. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. The staff, however, will evaluate this item during its review of an individual application for FDA/DC.

In its request for additional information dated April 10, 1990, the staff stated that Section 4.6 requires an extensive, fairly powerful, portable, wireless communication capability. This requirement requires extensive EMI/RFI testing of all safety electronics and probably should require testing of all control electronics for susceptibility. Existing, otherwise proven equipment has shown definite susceptibility to interference from wireless systems significantly less powerful than this proposed system. Analysis without testing may not be acceptable to the staff. By letter dated July 23, 1990, EPRI agreed that testing was required and stated that it would revise Section 4.6.3.6 to add the requirement.

In the DSER for Chapter 10, the staff identified testing for the effects of EMI/RFI on safety and control electronics as a confirmatory issue. The staff has verified that EPRI has added the requirement as stated above. Therefore, this DSER confirmatory issue is closed.

Section 4.6.3 also states a preference for telephone-type dial-up wireless equipment, with a requirement for open channel or "party line" communications for situations that require it. In the DSER for Chapter 10, the staff concluded that, although the requirements intended to ensure effective communications from any part of the plant are important to security communications and address concerns discussed in NRC Information Notice 83-83, "Use of Portable Radio Transmitters Inside Nuclear Power Plants", the dial-up telephone-type portable radio preferred by EPRI might not be suitable equipment for security armed response personnel. It identified the use of dial-up telephone-type portable radios for security purposes as an open issue. In its letter dated July 22, 1991, EPRI modified Chapter 10 to explicitly include security communications in the analysis and definition of specific communication needs required by Section 4.6.2.2 of that chapter. This change adequately addresses the staff's concern; therefore, this DSER open issue is closed.

10 CFR 73.55(e)(1) requires that onsite secondary power supply systems for nonportable communication equipment required by 10 CFR 73.55(f) be located in vital areas, which in turn are required by 10 CFR 73.55(c) to be located in a protected area. The staff states its concerns regarding the protection of the combustion turbine power supply in Section 4.2.3 of Chapter 11 of this report. Chapters 9 and 11 of the Evolutionary Requirements Document require a dedicated security system diesel generator and an uninterruptable power supply.

EPRI states that the communication system will be designed to be highly reliable and resistant to failures and that it will be powered from reliable, backed-up sources of onsite power. Section 4.6.4 of Chapter 10 states that the communication station in the main control room will be designed so that the operator can use more than one station easily and the communication equipment will not impede use of the monitoring or control equipment.

Different tones or lights will be used to alert the operator to specific communication equipment. The communication signals will be easily distinguishable from the other signals and alarms at the control station. The communication equipment will be identified so that it can be easily located.

Adequate voice communication will be possible between control room operators and technicians working in the control room. Because Section 4.7.6 of Chapter 10 specifies an ambient noise level of less than 60 dB(A) and the control room is designed to be relatively small, the staff considers this requirement will be achievable and concludes that it is acceptable.

The staff's evaluation of the human factors aspects of Section 4.6 of Chapter 10 is contained in Appendix D of this chapter.

4.7 Arrangement, Environment, and Equipment

Section 4.7 of Chapter 10 of the Evolutionary Requirements Document states that the arrangement of the M-MIS will be designed in accordance with the guidance in EPRI NP-3659. This guidance addresses those items that should be considered but does not provide specific design guidance.

EPRI states that the control stations will be arranged and have an environment and equipment suitable for the functions and tasks assigned to it. The staff concludes that this is a good design practice and is acceptable.

Section 4.7.2 of Chapter 10 states that the control stations also will have features that will enable the operators to complete the reporting, logging, and related activities that do not directly involve equipment control functions.

Test and maintenance provisions will be specifically included in the control station design. The staff concludes that this is a good design practice and is acceptable.

The control stations will have operator-adjustable lighting (between 10 and 50 foot-candles). EPRI indicates that this is consistent with the results documented in EPRI NP-5989, "Effects of Control-Room Lighting on Operator Performance, A Pilot Empirical Study."

The control station design also will include a list of materials, spare parts, and references that are to be stored at or near the control station.

The areas that will be continuously staffed will have an ambient noise level less than 60 dB(A), including the use of the emergency heating, ventilating, and air conditioning system. The staff considers this to be a positive goal and agrees with the EPRI rationale that it should be obtainable.

The Evolutionary Requirements Document specifies that continuously staffed areas will be provided with carpet and sound-absorbing walls and ceilings whose materials are selected for fire resistance and ease of upkeep. In its request for additional information dated April 10, 1990, the staff requested that, because of the expected quantity of electronic components that are susceptible to damage by static discharge, Section 4.7.7 also specify anti-static carpet. In its letter dated July 23, 1990, EPRI agreed with the comment and committed to revise this section.

In the DSER for Chapter 10, the staff identified use of antistatic carpet as a confirmatory issue. The staff has verified that EPRI has modified Section 4.7.7 to include the antistatic carpet for protection against static discharge. Therefore, this DSER confirmatory issue is closed.

The staff's evaluation of the human factors aspects of Section 4.7 of Chapter 10 is provided in Appendix D of this chapter.

4.8 Control Panels

Section 4.8 of Chapter 10 of the Evolutionary Requirements Document states that the panels for the M-MIS will be designed in accordance with EPRI NP-3659. The equipment location on a panel will be determined by the functions and tasks identified for the control station. Final arrangements will be determined after review in a full-scope simulator. The designer will provide a consistent approach to identifying the functional divisions of the panels and the components. The panels will be designed to facilitate future modification.

The design configuration drawings will include defined space for any required operator aids, which are also to be specified by the designer.

4.9 Requirements for Specific Control Stations

4.9.1 Main Control Room

Section 4.9.1 of Chapter 10 of the Evolutionary Requirements Document states that the design of the main control room (MCR) will be consistent with EPRI NP-3659.

EPRI specifies the basic requirement that the control stations will be designed to perform the tasks assigned to them. The designer will specifically identify paths to and from the MCR for specific tasks. Access by personnel to and from the MCR will not interfere with the activities of the control room operators.

EPRI states that the MCR will be designed to accommodate personnel other than direct operating staff. Access for NRC inspectors, utility management, personnel providing engineering assistance, personnel performing maintenance activities on MCR equipment, shift supervisor, and administrative support personnel will be included in the design of the MCR. Access also will be provided for fire brigades.

Two exits will be provided for MCR evacuation. Section 4.9.1.2.3 of Chapter 10 states that the remote shutdown stations will be accessible to operators evacuating the MCR from either of two independent exits without the use of security devices, such as keys or key cards, or electric power. The staff considers the remote shutdown panel to be vital equipment as defined by 10 CFR 73.2. Vital equipment is required by 10 CFR 73.55(c) to be located in a vital area, to which access from within the protected area requires passage through a physical barrier. All unoccupied vital areas are required by 10 CFR 73.55(d) to be locked and protected by an activated intrusion alarm system, and all points of personnel access to vital areas are required to be posi-tively controlled. If the remote shutdown stations and the MCR were part of a larger vital area, the requirements of both Section 4.9.1.2.3 and 10 CFR 73.55 would be met. If not, some accommodation may have to be made for Section 4.9.1.2.3.

The staff recognizes the importance of providing rapid access to remote shutdown panels. Provisions are included in 10 CFR Part 73 to accommodate the need for rapid ingress or egress of individuals during emergency conditions or situations that could lead to emergency conditions. In its letter dated July 13, 1990, the staff asked EPRI to supply additional information on how the requirements of Section 4.9.1 would be made compatible with all of the 10 CFR Part 73 requirements discussed above. By letter dated October 12, 1990, EPRI committed to include additional requirements in Sections 4.9.1, 4.9.3.6, and 4.9.3.8 of Chapter 10 that should provide protection against radiological sabotage resulting from unauthorized actuation of the remote shutdown stations. These requirements will limit the functions that could be taken away from the MCR and will alert the control room in a timely manner that the remote shutdown station has been actuated.

In the DSER for Chapter 10, the staff identified three confirmatory issues (one for Section 4.9.1 and two for Section 4.9.3). These additional requirements will cause the M-MIS designer to specifically consider the potential sabotage vulnerability of any controls added to a remote shutdown station to support normal plant operations and will ensure that annunciations in the main control room of actions to enable or transfer control to a remote shutdown station provide adequate time for operators and plant security to take action to preclude a serious accident. The staff has verified that EPRI has included the revisions in Sections 4.9.1, 4.9.3.6, and 4.9.3.8 of Chapter 10. Therefore, the three confirmatory issues are closed.

The staff concludes that the remote shutdown panel also needs to be protected from tampering that does not involve its actuation but could render it useless to operators if not discovered before it is needed in an emergency. In a letter dated October 12, 1990, EPRI stated that it is unlikely that positive means such as physical locks would be compatible with the functions of a remote shutdown station. If safety considerations are found to outweigh positive means of controlling access to the remote shutdown panel, the staff concludes that there should be some mechanism to detect unauthorized access, such as tamper-safe cabinet door alarms to annunciate access to displays and controls at normally unmanned vital control stations. The staff will evaluate proposed resolutions of this concern during its review of an individual application for FDA/DC.

Section 4.9.1.4 of Chapter 10 specifies that a restroom will be provided for the operators and that kitchen facilities will be provided near the control area for the operators' comfort.

Space will be provided in the MCR for shift turnover operations and for emergency equipment needed for control room personnel. The designer will identify any such equipment as part of the design and the assumptions for the need.

4.9.2 Local Control Stations

Section 4.9.2 of Chapter 10 states that the local stations will be considered part of the M-MIS and will be designed to the same criteria as the MCR. EPRI states that normal operation will not allow the controls in the MCR to be overridden from a local station or actions to be taken that generate a false display signal. However, this requirement allows such operations if it is impractical to design the M-MIS on this basis (during maintenance and testing). The MCR operator may have a control that permits override or indication that control has been lost. The staff concludes that this requirement allows designs that comply with current regulatory criteria and is acceptable.

For local control stations not normally used, EPRI states that less stringent environmental conditions are acceptable. Minimum levels of communication capability and lighting will still be maintained. In the DSER for Chapter 10, the staff concluded that this was not a good design practice. Stations predicted to be minimally used can still be very important and must still have adequate environments so that local actions can be taken safely. Although this requirement does not violate NRC regulations, EPRI should reconsider its appropriateness. The staff identified environmental conditions for minimally used local control stations as an open issue in the DSER. In its response dated January 28, 1992, EPRI stated that this requirement is intended to provide realistic limits and criteria for little-used local stations. The requirement, however, does not allow any condition to be predicted to prevent the operators from carrying out the assigned tasks under accident as well as normal operating conditions. This is acceptable because it does not conflict with current regulatory guidance. This DSER open issue is closed.

EPRI states that the stations will be designed for one-person staffing but will allow for two.

EPRI specifies that the designer will eliminate inadvertent actuation of controls at the local control stations as much as possible. In the DSER for Chapter 10, The staff concluded that this was a good design goal, but that EPRI had not provided detailed design guidance. It identified guidance on inadvertent actuation of controls at local control stations as an open issue. In its response dated January 28, 1992, EPRI stated that Section 4.5 references EPRI NP-3659, which has a subsection devoted to "strategies for preventing accidental actuation control." This response is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will evaluate this item during its review of an individual application for FDA/DC.

Positive means will be provided to prevent unauthorized use of normally unmanned stations that could have serious consequences. EPRI states that this requirement will not apply to stations needed for emergency use or where it otherwise will not be practical. As mentioned in EPRI's rationale, the designer must balance the conflicting considerations of security and ease of operator actions in an emergency. In its request for additional information dated April 10, 1990, the staff asked EPRI to describe the methods to be used to prevent unauthorized use, given the goal in Section 4.5.4 to eliminate the use of keys. By letter dated July 23, 1990, EPRI responded that the goal in Section 4.5.4 to eliminate the use of keys was only intended for areas, such as the MCR, that will be under the direct supervision of operators. Local control panels that will not be under direct supervision may be key locked to prevent accidental actuation or deliberate tampering. The staff concludes that this is consistent with current regulatory requirements and is acceptable.

In its letter of October 12, 1990, EPRI stated that, for those situations in which no positive means is practical, information indicative of unauthorized actuation provided to MCR operators as part of the normal plant annunciators and displays would meet the same standards of reliability as other information provided to those operators, rather than meeting security tamper-proofing standards. Because there is no requirement to use security standards for control room annunciators and displays, EPRI's response is acceptable.

4.9.3 Remote Shutdown Control Stations

Section 4.9.3 of Chapter 10 states that remote (outside the MCR) shutdown capability will be provided to go to hot standby and remain there indefinitely and to reach cold shutdown in 72 hours, if needed. As with the rest of the M-MIS, the designer will identify the functions and tasks to be performed at the remote shutdown stations. Since conditions requiring evacuation are unpredictable, no particular evacuation scenario can be assumed for the remote shutdown stations.

The plant simulator will include the remote shutdown stations and permit simulated shutdown using these facilities.

EPRI indicates that the remote shutdown stations will be designed with the assumption that a reduced number of staff may be available for short-term operation, that is, to bring the reactor to hot standby, but that a normal crew will be available for subsequent operations. The arrangement of the remote shutdown station will be the same as that of the MCR. The remote shutdown stations may be used for normal operations to avoid disruptions in the MCR.

Section 4.9.3.6 of Chapter 10 requires the designer to evaluate the possible routine use of the remote shutdown station to avoid disruptions in the MCR for testing or surveillance activities that could be performed elsewhere, to check the operational readiness of the remote shutdown station, and to keep operators familiar with the station. In the DSER for Chapter 10, the staff stated that EPRI had agreed in a letter dated October 12, 1990, to add a requirement that for any controls added to a remote shutdown station to support normal operations, the designer must consider the potential for increased vulnerability to insider sabotage based on the sabotage vulnerability analysis required by Section 5.2.2.1 of Chapter 9 of the Evolutionary Requirements Document. This was identified as a confirmatory issue. The staff has verified that this revision has been made (see Section 4.9.1 of this chapter). Therefore, this DSER confirmatory issue is closed.

Section 4.9.3.8 of Chapter 10 addresses the need to protect remote shutdown stations from unauthorized actuations. The proposed method is to annunciate (in the MCR) any unauthorized actions that might occur in the remote shutdown station. No other means of protection would be provided. In a letter dated October 12, 1990, EPRI committed to modify this approach by adding a requirement to Section 4.9.3.8 that M-MIS designers assess the annunciation (in the MCR) to ensure adequate time for the operators and plant security to take action to prevent a serious accident in the event of unauthorized use of a remote shutdown station. This was identified as a confirmatory issue in the DSER for Chapter 10. The staff has verified that this requirement has been added to Section 4.9.3.8. Therefore, this confirmatory issue is closed.

Section 4.9.3.9 of the original version of Chapter 10 required that the remote shutdown stations be in a building other than the one in which the MCR will be located and that it not be possible to open a single door to connect a room in the control complex with a remote shutdown station. In the DSER for Chapter 10, the staff stated that EPRI had committed, in a letter dated October 12, 1990, to delete the requirements for the location of remote shutdown stations from Chapter 10 and to place them in Section 4.6.5 of Chapter 6 of the Evolutionary Requirements Document. This was identified as a confirmatory issue. It has verified that Section 4.9.3.9 of Chapter 10 has been deleted. It has reviewed Chapter 6, Section 4.6.5.2, which addresses the control complex location, and Chapter 6, Section 4.6.5.3, which addresses access to remote shutdown stations. The staff concludes that these requirements in Chapter 6 would not prevent the control complex and the remote shutdown stations from being protected as vital areas as required by 10 CFR Part 73. Therefore, this DSER confirmatory issue is closed.

EPRI states that the designer will identify reference material, and space will be provided in the design for this material at the remote shutdown station. EPRI also states that the remote shutdown station will be functional regardless of a failure in the MCR and will be physically separated from the MCR. The staff concludes that this is the intent of the NRC requirement for a remote shutdown station and it is acceptable.

4.9.4 Emergency Response Support Facilities

Section 4.9.4 of Chapter 10 states that the emergency response support facilities will meet the requirements of 10 CFR 50.47(b) and Appendix E(IV) of 10 CFR Part 50. The criteria in NUREG-0696, "Functional Criteria for Emergency Response Facilities," and Section 8, "Emergency Response Facilities," of Supplement 1 to NUREG-0737 also will be used.

EPRI specifies that the technical support center (TSC) will be within a 2-minute walk of the MCR. Personnel in the TSC will be able to view the MCR activities through windows or closed-circuit television. The TSC may be used for normal operations as long as it remains fully available for emergency support.

EPRI considers the emergency operations facility (EOF) to be outside the scope of the Evolutionary Requirements Document. Therefore, the staff will evaluate the EOF design during its review of an individual application for FDA/DC.

Section 4.9.4.1 requires that, in an emergency, it be possible to modify normal security boundaries (using defined procedures) so that personnel can move between the MCR and the TSC without crossing a security boundary. In its July 13, 1990, request for additional information, the staff commented that procedures for modifying security boundaries in an emergency must be consistent with 10 CFR 50.54(x) and (y). By letter dated October 12, 1990, EPRI stated that if the plant owner intends to modify the normal MCR security boundary in an emergency, it expects that this will be covered by the technical specifications and that a specific plant procedure will be provided so that applying 10 CFR 50.54(x) and (y) will not be necessary. The staff concludes that this response is acceptable and will evaluate the provisions taken to address modifications of security boundaries during its review of an individual application for FDA/DC.

Section 4.9.4.3 of Chapter 10 states that the data available to the TSC and EOF will be the same as the data available in the MCR and will be displayed in the same format, insofar as practicable. The transmission of data to the TSC and EOF will be single failure proof.

EPRI specifies that processing capabilities will be provided for the TSC and EOF that do not place a burden on the plant process computer. In its request for additional information dated April 10, 1990, the staff asked EPRI to describe the data storage methods that are allowed. By letter dated July 23, 1990, EPRI responded that the designer will specify the detailed requirements and the Evolutionary Requirements Document will not specify or restrict any particular method. Therefore, the staff will address this issue during its review of an individual application for FDA/DC.

4.10 <u>Conclusion</u>

The staff concludes that the requirements in Section 4 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary

Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

5 DATA GATHERING, TRANSMISSION, AND PROCESSING REQUIREMENTS

5.1 Definition

Section 5.1 of Chapter 10 of the Evolutionary Requirements Document states that Section 5 provides the requirements that are needed to ensure proper acquisition, processing, and distribution of the data for plant control, monitoring, and protection.

The functions addressed in this section are those required to

- provide adequate data quality
- provide sufficient data-handling capacity
- meet the requirements without being restricted [illegible] particular equipment
- provide guidelines for appropriate data volume
- provide data requirements for the technical support center and emergency operations facility and for operator aids

5.2 General Requirements

5.2.1 Architecture

Section 5.2.1 of Chapter 10 of the Evolutionary Requirements Document states that the designer will establish the data system structure. Items for the designer to consider include minimization of the plant wiring, support of the maintenance and test requirements, and consideration of single component failure. Hard-wired or serial transmission is allowed if needed for speed or diversity. The designer will establish the number of "layers" and the number of data paths to be used.

The plant data system will be designed to accommodate the use of standard devices using standard protocols for the serial and parallel connections. The data system will be redundant and separated to the same extent as the systems to which it is connected.

It is customary for security computer systems at licensed power reactors to be independent of plant process computers. The protected area perimeter intrusion detection alarms and associated closed-circuit television (CCTV) signals may require a dedicated data transmission system to provide the data transmission speed necessary to meet the alarm assessment requirements of 10 CFR 73.55(h)(4)(i) and (ii). The staff concludes that Section 5.2.1.1 of Chapter 10 contains nothing that would preclude such an independent data transmission system for perimeter intrusion alarms. However, it will evaluate the capability of the alarm assessment system to meet the requirements of 10 CFR 73.55(h)(4) during its review of an individual application for FDA/DC.

5.2.2 Design Process Requirements

Section 5.2.2 of Chapter 10 specifies that the data system will be consistent with the same design guidance as that for the rest of the M-MIS. The signals provided will be designed to support their use with a minimal use of special high-performance devices. The design process will include guidelines for determining data system characteristics.

In the DSER for Chapter 10, the staff stated that this section was acceptable but noted that EPRI had not provided guidance for implementing the requirement; therefore, it identified guidance on data system characteristics as an open issue. In its response dated January 28, 1992, EPRI stated that the plant designer's responsibility was designing the system, and any additional guidelines would be an encroachment on the plant designer's responsibility. The staff concludes that this is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, because EPRI has not provided guidance for implementing the requirements, the staff will evaluate this item in detail during it review of an individual application for FDA/DC.

5.2.3 Performance Requirements

Section 5.2.3 of Chapter 10 specifies that the multiplexers, data communication links, and network links will have sufficient (approximately 40 percent) performance margin under conditions of maximum stress and that the designer will evaluate failures and operator actions. The multiplexers will have reasonable expansion capability that would permit the utility to add functions in the future. Section 5.2.3.2 of Chapter 10 states that the expansion capability should be a minimum of 25 percent. However, Section 5.2.3.3 indicates that a 30-percent expansion capability should be provided.

In the DSER for Chapter 10, the staff stated that these numbers were not consistent and should be clarified and identified the expansion capability of multiplexers as an open issue. In its response dated January 28, 1992, EPRI stated that the intent of the requirement in Section 5.2.3.2 was (1) to specify the physical requirement of accommodating up to 25 percent additional input/output signals in the data acquisition hardware and (2) to ensure all of the required functions were performed within the allocated time interval by providing sufficient design margin in the processor time. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed.

5.2.4 Reliability and Availability

Section 5.2.4 of Chapter 10 states that the data system will meet the reliability and availability requirements of the system that will use the information. When redundant data paths and signal selection are used, the reliability model of the data path will include consideration of the failure rate and coverage provided by the selection device or algorithm. The reliability analysis must include consideration of cases where the selection algorithm or device will not detect all failures or data anomalies. The measurement of reliability and availability is addressed in previous sections of the Evolutionary Requirements Document.

5.2.5 Signal Transport Delay

Section 5.2.5 of Chapter 10 states that the plant designer will analyze the propagation time for multiplexed data to ensure stability in closed-loop control. The time delays will be considered to ensure that the end actions occur within the allocated time. Response degradation due to filters, sampling rate, analog-to-digital (A/D) conversions, and so forth, will be included in the propagation time.

As discussed by the staff in Section 5.2.1 of this chapter, some security functions require rapid response of information systems. The staff expects that the provision in Section 5.2.5.1 of Chapter 10 for an analysis to "demonstrate the prevention of significant degradation in performance of plant control and monitoring systems" will allow the designer the flexibility to provide a dedicated security data transmission and processing system if needed to meet NRC alarm assessment requirements.

EPRI states that operator control feedback will be determined by human factors analysis. The design will provide for acknowledgment of a requested action to the operator within 0.25 second. The system will not introduce more than the 1.5 seconds of delay to a display that is currently used in hard-wired systems. Since this is a reduction in system capabilities from those of hard-wired systems currently used, the staff asked EPRI, in its request for additional information dated April 10, 1990, to provide justification for this reduction. In a letter dated July 23, 1990, EPRI responded that the designer will consider the time delay and will justify that the response time of the system is adequate. The staff will address this concern during its review of an individual application for FDA/DC.

5.2.6 Standardization

Section 5.2.6 of Chapter 10 indicates that the system will be standardized to the extent practicable.

5.2.7 Communication Protocols

Section 5.2.7 of Chapter 10 states that standard communication protocols will primarily be used in the design, as previously mentioned.

5.3 <u>Data Gathering Requirements</u>

Section 5.3.1 of Chapter 10 of the Evolutionary Requirements Document states that the designer should consider the following data signal characteristics for analog signals:

- accuracy
- resolution
- sample rate
- repeatability
- response rate
- safety classification
- range

The staff concludes that the list is not complete. However, the characteristics listed do not conflict with regulatory requirements and are, therefore, acceptable.

EPRI states that the data gathering process for discrete and pulse input signals will provide

- noise immunity
- sufficient response

- voltage supply for dry contact input
- switch debounce where needed
- identification of failure modes

The signal provided will meet the most restrictive value of each requirement for all of the systems that will use the signal.

Section 5.3.2 of Chapter 10 specifies that each data acquisition channel will be provided with noise filters to eliminate spurious trips. A/D conversion will be provided with aliasing filtering as needed. The staff concludes that this is a good engineering design and is, therefore, acceptable.

5.4 Data Transmission

Section 5.4.1 of Chapter 10 states that all data on the plant-wide data buses will have signal identification information associated with them. Where precise timing information is important, time information will be attached to the signal. Data will have a signal quality tag associated with it so that data errors can be tracked to the source of the problem.

Section 5.4.2 of Chapter 10 specifies that the multiplexing system will provide sufficient fidelity design so that random bit errors will not degrade the reliability of the systems. The goal provided in this section is that less than 1 of 1.0E+10 signal transmissions cause "significant" errors in the operator's displays. Using the EPRI estimate of 5.0E+8 signals per day, there will be a significant error every 20 days.

In the DSER for Chapter 10, the staff stated that EPRI should clarify the definition of "significant" for this item and identified the reliability of the multiplexing system as an open issue. In its response dated January 28, 1992, EPRI stated that it had addressed this issue in its letter dated May 17, 1991. In addition, Section 5.4.2 of Chapter 10 has been revised to clarify the definition of "significant." This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed.

5.5 Signal Processing

Section 5.5 of Chapter 10 of the Evolutionary Requirements Document states that the signal processing will ensure that the accuracy, precision, and rate of response are consistent with the applications. The data system will provide signal validity checks. The primary emphasis of this section is to ensure that the signal processing does not corrupt the signal. The staff concludes that this is good design practice and is, therefore, acceptable.

5.6 Operator Aids

Section 5.6 of Chapter 10 of the Evolutionary Requirements Document states that any operator aids provided will include self-diagnostics to warn the operator whenever the system is malfunctioning or unavailable.

Section 5.6.1 of Chapter 10 states that the designers will provide a technical specification monitoring function that will have the capability to warn the operator when a limiting condition for operation (LCO) is being approached or violated. The system will automatically acquire the results of automatic testing that could affect the LCO and will automatically log all LCO violations. Because EPRI's general requirement is that all systems receive the same level of verification and validation as the safety systems, the staff concludes that this requirement is acceptable.

Section 5.6.2 of Chapter 10 states that the designer will provide the capability to monitor the availability of the emergency safety features initiating and actuating equipment.

Section 5.6.3 of Chapter 10 provides for the automation of testing, planning, and logging to reduce some of the operator burden. Monitoring and trending that identify the degradation of equipment before total failure will be implemented where possible.

5.7 Hardware

Section 5.7 of Chapter 10 describes the general hardware requirements specified by EPRI.

The Evolutionary Requirements Document specifies that module configuration by back-plane wiring is preferable to on-card configurable switching. EPRI believes that the necessary accuracy, resolution, and speed needed for the ALWR applications will easily be met by most analog-to-digital (A/D) and digital-to-analog (D/A) convertors and, therefore, does not specify any particular requirements other than the general criterion that the selected device be suitable for its application. The staff concludes that the requirements in this section are acceptable. However, because all A/D and D/A convertors are not acceptable for all applications, the staff will evaluate specific details during its review of an individual application for FDA/DC.

5.8 Conclusion

The staff concludes that the requirements in Section 5 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are, therefore, acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan, or provide justification for alternative means of implementing the associated regulatory requirements.

6 COMMON SOFTWARE, HARDWARE, AND CONTROL REQUIREMENTS

Section 6 of Chapter 10 of the Evolutionary Requirements Document addresses the common software, hardware, and control requirements for the design, implementation, and installation of the M-MIS. All systems listed in Chapter 10 of the Evolutionary Requirements Document will meet these requirements. The staff's evaluation of the human factors aspects of this section is given in Appendix D of this chapter.

6.1 Common Software Requirements

6.1.1 Definition

Section 6.1.1 of Chapter 10 of the Evolutionary Requirements Document originally defined the M-MIS software to include all software and firmware required for the operation and maintenance of the plant. EPRI stated that the requirements did not necessarily apply to software used for design aids.

In the DSER for Chapter 10, the staff stated that it might be appropriate that these criteria be applicable for some design aids and that EPRI should include a requirement that the designer identify the design aids used and provide justification for any that did not meet these requirements. It identified software design aids and tools as an open issue. In its response dated January 28, 1992, EPRI stated that it had revised the Evolutionary Requirement Document to require that all software prepared by the plant design organization, purchased software, and software supplied with the purchased system and equipment as part of the plant follow an acceptable verification and validation program. The staff agrees with the inclusion of design aids required for the operation and maintenance of the plant. Therefore, this DSER open issue is closed.

6.1.2 Design Process

Section 6.1.2 of Chapter 10 states that safety-related software will meet the quality assurance requirements of Appendix B to 10 CFR Part 50 as described in NUREG/CR-4640, "Handbook of Software Quality Assurance Techniques." However, non-safety-related software is not addressed. In the rationale portion of this section, EPRI describes four basic categories of software.

(1) application software, which includes the plant design calculations and plant operating software

(2) support software, which includes operating systems, compilers, assemblers, development stations, debuggers, editors, data bases, mathematical subroutines, system libraries, and utilities

(3) test and maintenance software used to carry out testing, operation, and maintenance functions

(4) training software used for instruction and in simulators

In the DSER for Chapter 10, the staff stated that these descriptions were acceptable for use in the following discussions. It noted that the operation function listed in the third category applied only to the test and maintenance function and not to plant operation (which is included in the first category). The requirement for safety-related software to meet Appendix B to 10 CFR Part 50 was acceptable. However, the Evolutionary Requirements Document should be more specific in the listing of applicable criteria. More specific requirements (such as ASME NQA-2A, Part 2.7) could be referenced and would provide additional guidance for the type of equipment described in the Evolutionary Requirements Document.

In the .R for Chapter 10, the staff identified quality assurance requirements for safety-related software as an open issue. In its response dated January 28, 1992, EPRI stated that Volumes II and III of the Requirements Document would be revised to list more specific requirements and that it would delete the last sentence and replace the next to last sentence of Section 6.1.2.1 with the following:

For safety-related software, the SQAP [Software Quality Assurance Program] shall comply with the requirements specified in the following documents: (a) 10 CFR Part 50, Appendix B; (b) ASME NQA-2A, Part 2.7, "Quality Assurance Requirements of Computer Software for Nuclear Facility Applications"; (c) Regulatory Guide 1.152, "Criteria for Programmable Digital Computer System Software in Safety-Related System of Nuclear Power Plants"; (d) ANSI/IEEE-ANS-7-4.3.2, "American National Standard Application Criteria for Programmable Digital Computer Systems in Safety Systems of Nuclear Power Generating Stations."

The staff has verified that EPRI has included this guidance. Therefore, this DSER open issue is closed.

EPRI requires that a software life cycle be developed and used for all software developed by the M-MIS designer. In its request for additional information dated April 10, 1990, the staff asked EPRI to add requirements for support software so that any future identified errors and changes are reviewed for possible impact on installed software. In the DSER for Chapter 10, the staff identified the impact of support software on installed software as a confirmatory issue because in a letter dated July 23, 1990, EPRI had committed to revise Section 6.1.2 of Chapter 10, as requested by the staff. The staff has verified that the revisions have been made; therefore, this DSER confirmatory issue is closed.

Section 6.1.2.3 of Chapter 10 describes the software life-cycle phases. A list of minimum requirements is provided. However, in the DSER for Chapter 10, the staff concluded that a configuration-management requirement similar to IEEE 828-1983, "IEEE Standard for Software Configuration Management Plans," should also be included and identified configuration-management requirements for software as an open issue. In its response dated January 28, 1992, EPRI stated that it had added to Section 6.1.2.18 of Revision 1 a requirement to meet the guidelines for software configuration management specified in ANS/IEEE 1042. This standard provides guidance on the implementation of the software configuration-management plan specified in ANSI/IEEE 828. The staff agrees with the use of this standard; therefore, this DSER open issue is closed.

EPRI requires the M-MIS designer to prepare a software requirement specification. The staff notes that this applies only to safety and non-safety-related software developed by the M-MIS designer. The staff will review this specification during its review of an individual application for FDA/DC.

The Evolutionary Requirements Document specifies that the M-MIS designer will define the algorithms, equations, logic, and data operations.

EPRI requires that a software verification and validation (V&V) plan be developed in accordance with ANSI/IEEE 730, "Software Quality Assurance Plans"; ANSI/IEEE 829, "Software Test Documentation". In the DSER for Chapter 10, the staff concludes that these standards are suitable for establishing quality assurance plans and documenting testing, but they are not adequate for establishing a V&V plan. The requirement in Chapter 1 of the Evolutionary Requirements Document to meet Regulatory Guide (RG) 1.152, is an acceptable method for establishing a V&V plan and that guide in addition to the standards listed above is acceptable. However, EPRI should consider referencing additional standards such as ANSI/IEEE 1012-1986, "IEEE Standard for Software V&V Plan," and International Electrotechnical Commission (IEC) 880-1986, "Software for Computers in the Safety Systems of Nuclear Power Stations." These standards provide guidance for V&V plans that are acceptable to the staff to meet RG 1.152.

In the DSER for Chapter 10, the staff identified guidance on V&V plans as an open issue. In its response dated January 28, 1992, EPRI stated that even though Section 6.1.2 3 does not specifically reference IEEE 1012-1986, Section 6.1.2.6 specifies that the standard will be met. EPRI also stated that the reference to IEC 880-1986 was not necessary because the plant designer must justify that the V&V plant meets the guidelines of IEEE 1012-1986, which relates to the same subject. Since the staff agrees with the use of IEEE 1012-1986 for software verification and validation because it does not conflict with current regulatory guidance, this DSER open issue is closed.

Section 6.1.2.7 of Chapter 10 states that the M-MIS or plant designer will develop a software V&V report to provide the results of the V&V. The staff concludes that this is a standard requirement for good software design procedures and is, therefore, acceptable.

EPRI states that the M-MIS designer will establish a coding standard so that each software module is formatted like every other. The software will be designed with descriptive statements and comments incorporated. The staff concludes that this is good software design practice and is, therefore, acceptable.

EPRI states that the M-MIS designer will use code analysis to verify that the computer program correctly implements the design. The staff concludes that code analysis is a useful verification technique that does not conflict with current regulatory requirements and is, therefore, acceptable. However, it is not adequate by itself, and other methods of verification will be required to support a specific design application. Therefore, the staff will address this issue during its review of an individual application for FDA/DC.

EPRI states that the designer will provide user documentation. In the DSER for Chapter 10, the staff stated that EPRI should reference sources of additional guidance, such as ANSI/IEEE 1063-1987, "Standard for Software Users

Documentation," and identified guidance on software user documentation as an open issue. In its response dated January 28, 1992, EPRI stated that Section 6.1.7.2, Revision 1, references ANS/IEEE 1063. Since the staff agrees with the use of ANS/IEEE 1063, this DSER open issue is closed.

EPRI considers commercially available software acceptable if the purchasing organization performs acceptance tests or V&V on it. In the DSER for Chapter 10, the staff stated that the general concept of using commercially proven software was acceptable. However, the requirement for acceptance testing was vague, and EPRI should clarify it. The staff identified acceptance testing of commercially available software as an open issue. In its response dated January 28, 1992, EPRI stated that Revision 1 of the rationale portion of Section 6.1.7.2 of Chapter 10 lists Regulatory Guide 1.152 and ANSI/IEEE ANS-7.4.3.2. EPRI also stated that the rationale portion of Section 6.1.7.2 of Chapter 10 (Volumes II and III of the Requirements Document) will be revised to require the guidance of IEEE 1008-1987, "IEEE Standard for Software Unit Testing." The staff agrees with the use of this standard. Therefore, this DSER open issue is closed. However, the dedication of commercial software is a vendor- or utility-specific item.

The testing performed as required by Section 6.1.2.12 of Chapter 10 will be documented for later review by the utility. After testing and/or verification, the software will be placed under configuration control. The staff concludes that this requirement is acceptable and will address this issue during its review of an individual application for FDA/DC.

The purchase of software from clearinghouses that permit read-only access is allowed in the Evolutionary Requirements Document. The clearinghouse will maintain the configuration control, but the purchasing group will be responsible for the accuracy of calculational results, identification of software errors, and identification of the impact of errors identified by other users. However, no information is provided as to how this is to be done. The staff is also concerned that this may not be viable for safety system software. The staff will address this concern during its review of an individual application for FDA/DC.

Section 6.1.2.16 of Chapter 10 requires the software designer to maintain records of all commercially purchased software. It also requires the purchasing group to have a systematic method of informing users of changes required in the software. In the DSER for Chapter 10, the staff stated that no information was provided in this section as to how a utility was to be informed of a subtier (e.g., an operating system or compiler) error by a software designer who is not required to comply with the requirements of 10 CFR Part 21 and may not be aware of all of the uses of the product. The staff concluded that EPRI should provide guidance on how this should be done and identified notification of software errors or modifications of commercially delivered software products as an open issue. In its response dated January 28, 1992, EPRI stated that it would add requirements that the plant designer establish and maintain a software configuration management program for all software, commercially purchased or custom developed. In addition, it would require the plant owner to establish a software configuration management plan and software configuration management program in accordance with IEEE 828 and 1042, respectively, after the plant designer turns over the plant to the owner. The staff agrees with the use of these standards; therefore, this DSER open issue is closed.

EPRI states that new software that needs to be developed will have to meet all of the requirements in Section 6.1.2 of Chapter 10 of the Evolutionary Requirements Document. In the DSER for Chapter 10, the staff stated that EPRI did not address how long-term configuration control will be maintained if several non-Class 1E vendors are involved and identified long-term configuration control of software as an open issue. In its response dated January 28, 1992, EPRI stated that it had addressed configuration management as part of its response to the open issue regarding notification of software errors or modifications of commercially delivered software products. The staff agrees that this response is acceptable. Therefore, this DSER open issue is closed.

6.1.3 Software Design

Section 6.1.3 of Chapter 10 states that software will be developed using a top-down structured approach. The Yourdon methodology is the approach preferred by EPRI. As this approach has been widely used and proven, the staff concludes that its use in the software design process is acceptable. However, in the DSER for Chapter 10, the staff identified clarification of the top-down structured design approach as an open issue. In its response dated January 28, 1992, EPRI stated that it would revise the Evolutionary Requirements Document to require a top-down structured design approach for all software developed by the plant designer or specified by the plant designer for the plant design. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed.

EPRI states that software documentation will be developed along with the design. The software should be designed to reject out-of-bounds inputs. The staff concludes that this is a good engineering practice and is, therefore, acceptable.

The Evolutionary Requirements Document states that the software design will avoid convoluted software structure. In the DSER for Chapter 10, the staff stated that no guidance was provided on how to determine if this requirement is satisfied. It identified guidance on convolution of software structure as an open issue. In its response dated January 28, 1992, EPRI stated that it would revise the Evolutionary Requirements Document to require that the software development plan include meeting (1) the requirements and methodology for achieving modularity and (2) the methodology for ensuring that the software is both auditable and testable during the design, implementation, and integration phases. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will review this item in detail during its review of an individual application for FDA/DC.

EPRI states that operating system software will not be modified by the downstream users. Section 6.1.3.6 of Chapter 10 discusses portability and upward compatibility when updated and new operating system software is released. In its request for additional information dated April 10, 1990, the staff noted that extreme care and control were needed in this area, because there have been many examples of updated software that was not completely compatible. By letter dated July 23, 1990, EPRI agreed with the staff's comments, but did not propose any additional guidelines in this area.

Section 6.1.3.7 of Chapter 10 states that a hierarchical design structure and principles of modular design will be used in the software design.

EPRI states that the designer will identify assumptions and will specify how the program will behave if the assumptions are violated. In the rationale portion of Section 6.1.3.8, EPRI notes that fault-tolerant design allows the software to continue functioning in spite of failures. In the DSER for Chapter 10, the staff concluded that the statement about fault tolerance was acceptable, but noted that the requirement did not specify a fault-tolerant system, only one in which the results of the faults are known. The staff concluded that EPRI should address how this information will be determined for commercial software and identified the behavior of commercial software when assumptions are violated as an open issue. In its response dated January 28, 1992, EPRI stated that Section 6.1.2.12 requires the plant designer to perform extensive validation testing for commercial software to determine the information regarding fault tolerance. The staff agrees with this testing requirement. Therefore, this DSER open issue is closed. However, the staff will review this item in detail during its review of an individual application for FDA/DC.

Section 6.1.3.9 of Chapter 10 states that a minimum of different types of support software will be used. In its request for additional information dated April 10, 1990, the staff asked EPRI to address the tradeoff between potential software common-mode errors and the problems associated with using diversity in the design. By letter dated July 23, 1990, EPRI stated that it would revise Section 4.5.6 of Chapter 10 to require the provision of diverse, manual backup controls for safety systems. In addition, EPRI committed to add a new requirement to Section 3.5.3 of Chapter 10 to treat common-mode failures in general. EPRI stated that it believes it is prudent to invest the available resources in one set of software and require stringent design. In the DSER for Chapter 10, the staff concluded that these requirements did not conflict with regulatory requirements and were, therefore, acceptable and identified this as a confirmatory issue. The staff has confirmed that these changes have been incorporated into the Evolutionary Requirements Document. Therefore, this confirmatory issue is closed.

EPRI states that support software will be proven commercial software packages. Programming will be done in a high-level language such as FORTRAN. Assembler-level languages will be used only for low-level routines. The software is to be designed to be as machine independent as possible. The staff notes that although these requirements will be difficult to enforce for the use of commercial packages and support software, they do not conflict with regulatory requirements and are, therefore, acceptable.

EPRI states that the M-MIS designer will provide a plan for providing software support to the utility, including operating systems and compilers. This is a necessary ingredient for resolving the staff concerns discussed above and is, therefore, acceptable.

Section 6.1.3.14 of Chapter 10 states that the M-MIS functions of protection, control, alarm, and display will be based on digital technology. This technology will have the following characteristics:

- software that is capable of being verified and validated
- a final source program that will be readable from start to end
- self-supervision of control flow and data
- common software language
- no assembly language for protection or control

- standard software structure
- continuous-loop, noninterruptible design
- global variables that will be located in a common region

In its request for additional information dated April 10, 1990, the staff stated that the use of common software language may minimize the potential for errors if significant V&V efforts are focused on that program. Common-mode failures may be more likely with some of the possible microprocessor-based systems than with previous analog designs. In a letter dated July 23, 1990, EPRI stated that it considered it important to evaluate potential software common-mode errors and committed to add a requirement to Section 3.5.3 of Chapter 10 to have the designer provide such an evaluation. In the DSER for Chapter 10, the staff concluded that this was acceptable and identified this as a confirmatory issue. The staff has verified that this change has been incorporated into the Evolutionary Requirements Document. Therefore, this confirmatory issue is closed.

Section 6.1.3.15 of Chapter 10 states that comprehensive diagnostic programs will be performed at initialization. It requires the provision to bypass the diagnostic routines during maintenance. In the DSER for Chapter 10, the staff concluded that EPRI should clarify the intent of this requirement. An acceptable interpretation of this requirement would be for the diagnostics to be bypassed when the maintenance is actually being performed and then restored before restart. However, an unacceptable interpretation would be to perform maintenance and return the equipment to service without the initial diagnostics. The staff identified diagnostic bypass during maintenance as an open issue in the DSER.

In its response dated January 28, 1992, EPRI stated that Section 6.1.3.15 had been revised to require that the diagnostics be run before the equipment is put back in service. The staff agrees that this is acceptable. Therefore, this DSER open issue is closed.

EPRI states that the programs will be developed in modular form and then linked.

Section 6.1.3.17 of Chapter 10 states that parameters that may change because of plant conditions will not be hard-coded so that the code would have to be recompiled to change a parameter. In the DSER for Chapter 10, the staff concluded that EPRI should provide additional guidance on memory protection. For example, attempts at writing to protected memory should be specifically prevented. EPRI should also specify restrictions on the acceptable range within which an operator may make a change. The staff identified guidance on memory protection as an open issue.

In its response dated January 28, 1992, EPRI stated that it would add requirements that the M-MIS designer establish and document the vital software required to reside in protected memory. In addition, it would also require the M-MIS designer to specify the restrictions on the range and provide steps to protect against and/or alert the operator to making constant changes beyond the specified range. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will review this item in detail during its review of an individual application for FDA/DC.

EPRI states that a function that is widely used will be installed as a utility module that can then be shared by other software modules.

Section 6.1.3.19 of Chapter 10 states that specific steps will be taken to limit the possibility of software viruses. In the rationale portion of this section, EPRI notes that this is a developing area and it is therefore premature to specify detailed requirements. Examples given by EPRI include physically limiting access to input devices, independent verification of the validity of the input, software check sum techniques, and bit-by-bit comparison with secure copies of the software. The staff notes that although this list of examples does not include the use of software programs contained in read-only memory as firmware, the Evolutionary Requirements Document does not exclude such designs. The requirements of this section do not violate NRC requirements and are, therefore, acceptable.

Section 6.1.3.20 of Chapter 10 describes the data base management requirements that the M-MIS designer is to provide.

EPRI states that process control and monitoring data that are updated will be stored in random access memory. Data that are used to define the plant will be stored in nonvolatile memory with the capability for integrity checking. In the DSER for Chapter 10, the staff concluded that EPRI should clarify the requirement that redundant safety-related devices should not use the same data base. The staff interprets this requirement to mean that the redundant safety channels will use the same information but that the information will be located in separate physical modules. The staff concluded that EPRI should clarify the requirement to ensure that no redundant safety channels share the same modules until the point of logic voting and identified the use of information by redundant safety channels as an open issue. In its response dated January 28, 1992, EPRI stated that the intent of this requirement was to ensure that no redundant safety channels share the same modules until the point of logic voting. The staff agrees with EPRI's intent; however, it is concerned about the potential reduction in the safety margin by interaction of the information system with the safety-related system. Therefore, it will review this item in detail during its review of an individual application for FDA/DC. This DSER open issue is closed.

EPRI states that the use of rotary buffers is to be avoided. The staff concludes that this is good engineering practice and is acceptable.

In its request for additional information dated April 10, 1990, the staff asked EPRI whether the use of expert systems was restricted or encouraged. By letter dated July 23, 1990, EPRI responded that the use of expert systems does not currently meet the proven-technology requirement, but they may be used in the future. The staff concludes that the response is acceptable. However, there are no acceptance criteria for expert or artificial intelligence systems, and the staff considers such systems unacceptable for use in safety systems until such criteria are established and approved. The staff does not believe that the expert systems have been demonstrated to be deterministic in nature and that they can be adequately verified and validated.

6.1.4 Performance Requirements

Section 6.1.4 of Chapter 10 states that the computer system will be designed with about 40-percent extra performance margin to account for future expansion and uncertainties. The performance of the system will be measured to verify the margin. The staff concludes that this is good engineering practice and is, therefore, acceptable.

The computer system will have on-line diagnostics and will have the capability to do both hardware and software checks.

6.1.5 Verification, Testing, and Qualification

Section 6.1.5 of Chapter 10 states that the designer will develop tools as needed to improve the quality and reliability of the software. In the DSER for Chapter 10, the staff stated that though the rationale portion provided a list of many tools, such as debuggers and test drivers, the requirement did not provide any specific guidance or recommendations. The staff concluded that EPRI should consider providing such guidance and identified this as an open issue. EPRI's position is that the tools will be developed to the same level as the delivered software. The staff concludes that this should include performing verification and validation (V&V) on software tools used to develop safety software to the same level as the V&V performed on the safety software itself and considered this part of the open issue concerning software design aids and tools discussed in Section 6.1.1 of this chapter. Therefore, this open issue is closed.

The software tools will be maintained under configuration management control. EPRI recommends that the tools be coded in high-level languages if possible.

EPRI states that the testing will consist of both human and computer-based testing.

Section 6.1.5.6 of Chapter 10 states that the test program objectives will be to locate programming errors and to validate that the software performs correctly. In the rationale, EPRI states the need to perform a reasonable amount of testing to provide a sufficient degree of confidence that the software is correct. In the DSER for Chapter 10, the staff concluded that this requirement was acceptable. However, it identified the definition of reasonable testing and sufficient degree of confidence as an open issue and recommended that EPRI define how much testing is "reasonable" and what is a sufficient degree of confidence. In its response dated January 28, 1992, EPRI stated that it would add requirements to state that it is acceptable to use the guidelines in IEEE 1012, 981.1, and 981.2 to determine the testing required. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will review this item in detail during its review of an individual application for FDA/DC.

EPRI states that the testing personnel will not be the individual or group who developed the design. The staff concludes that this requirement is acceptable. However, the level of independence should be at least through the first level of management. This is necessary to ensure that the testers and verifiers are removed from the time and cost constraints that are usually present in developing a product. This is discussed as part of the open issue concerning software verifiers in Section 3.1.2 of this chapter.

The tester will predict the results before running the tests in order to avoid interpreting errors as correct results. The staff concludes that this is a good practice and is, therefore, acceptable.

EPRI states that the testability, calibration, and bypass requirements of IEEE 279, "Criteria for Protection Systems for Nuclear Power Generating Stations," will be supported in a software-based design.

6.1.6 Availability and Reliability

Section 6.1.6 of Chapter 10 states that the planning of the V&V will include systematic quality assurance activities.

EPRI requires the M-MIS designer to evaluate the diversity and redundancy needed for each system. The designer will consider the need for a hard-wired backup to the computer-based system. In the DSER for Chapter 10, the staff concluded that diversity in the basic technology could probably eliminate the need for diversity in software. In the rationale, EPRI correctly expresses the NRC staff concerns that software-based safety systems may contain subtle failure modes that occur only under an obscure set of conditions that may involve environmental factors as well as internal hardware or software failures. If the software failures were random, a multidivision safety system might provide the redundancy to back up such failures. However, if standardized software is used throughout the system, common-mode failures could degrade the overall safety system operation. The staff concludes that the resolution of this concern may require that various forms of hardware and software diversity be incorporated into the system designs. The staff agrees with EPRI that there are many different methods to obtain diversity.

In the DSER for Chapter 10, the staff identified specification of the level of diversity in safety systems as an open issue and recommended that some specific level of diversity in safety system be required. In its response dated January 28, 1992, EPRI stated that requirements for manual backup controls had been added to Section 4.5.6 and Section 4.4.8.2 of Chapter 10 (Volumes II and III of the Requirements Document). These additional requirements provide significant diversity in the design and are acceptable. Therefore, this DSER open issue is closed. However, because vendors have proposed different approaches to address this issue, the staff will review the approaches during its review of individual applications for FDA/DC.

Section 6.1.6.3 of Chapter 10 requires that a reliability evaluation be performed. However, there appears to be little consensus in the industry as to how best to accomplish the task. Although there are IEEE standards (such as ANSI/IEEE 982.1-1988, "IEEE Standard Dictionary of Measures To Produce Reliable Software," and IEEE 982.2-1988, "IEEE Guide for the Use of IEEE Standard Dictionary of Measures To Produce Reliable Software"), that provide guidance in this area, the nuclear industry has not widely accepted any method. In the DSER for Chapter 10, the staff concluded that EPRI should specify guidance on acceptable methods to perform such a reliability evaluation and identified this as an open issue. In its response dated January 28, 1992, EPRI stated that the intent of this section is to ensure that the designer achieves high-quality software as part of the design effort. The staff concludes this response is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed.

EPRI states that security protection will be provided to prevent unauthorized or inadvertent changes to software and data.

Section 6.1.6.5 of Chapter 10 requires that software-based safety systems satisfy the basic design principles of defense-in-depth, redundancy, separation, independence, and diversity. EPRI states that the specific details of how to accomplish this are to be examined during the design process. In the rationale, EPRI notes that the NRC staff has been concerned that the existing regulatory criteria do not address the special design requirements of computers.

NUREG-0493 is given as an example of guidance for performing a common-mode failures analysis. EPRI states that the test program objectives will be to locate programming errors and validate review in this area. In the rationale, EPRI describes a method of carefully distributing diverse modules through the systems to avoid the need for extensive diversity. The staff concludes that this requirement is acceptable, but it only requires that there be enough diversity in the safety systems to sufficiently minimize the potential for common-mode failures caused by software problems. The staff will evaluate this issue during its review of an individual application for FDA/DC.

Although Section 6.1.6.5 of Chapter 10 refers to IEEE 603, there is no commitment to invoke it or its supplement, ANSI/IEEE-ANS-7-4.3.2 (Regulatory Guide 1.152). The staff concludes that the commitment to Regulatory Guide 1.152 in Chapter 1 of the Evolutionary Requirements Document without comment is not acceptable because of the very different interpretations of this regulatory guide by the vendors. In its request for additional information dated April 10, 1990, the staff asked EPRI to discuss more fully the V&V commitments in this chapter. In a letter dated July 23, 1990, EPRI stated that Section 6.1.2 of Chapter 10 contains the requirements for the design process, quality assurance, and V&V that describe elements of a software design process that experience has shown will produce high-quality software. Section 6.1.2 of Chapter 10 recommends the use of such guidance documents as NUREG/CR-4640, ANSI/IEEE 730, and ANSI/IEEE 829. As discussed in Section 6.1.2 of this chapter, the staff concludes that these documents provide guidance pertaining to quality assurance (QA) and testing documentation that the staff agrees provides an acceptable approach for QA. However, it does not consider these documents adequate to develop a V&V plan for safety software. EPRI concluded its response by stating that the standards and regulations regarding the design of computer-based controls were evolving; therefore, it deemed it inappropriate to include an exhaustive list of standards and regulations in the Evolutionary Requirements Document. As discussed in Section 6.1.2 of this chapter, the staff concludes that there is not enough information concerning software V&V in the Evolutionary Requirements Document to provide confidence that a vendor following this guidance would meet NRC requirements. Therefore, the staff will review V&V conformance during its review of an individual application for FDA/DC.

6.1.7 Maintainability and Serviceability

Section 6.1.7 of Chapter 10 states that the equipment manuals provided by the vendors to the M-MIS designer should be provided to the utility. The designer will provide all the documentation and tools required to maintain and modify the system to the utility.

6.2 Common Hardware Requirements

6.2.1 Definition

Section 6.2.1 of Chapter 10 of the Evolutionary Requirements Document defines the common requirements for the design, selection, and installation of the M-MIS hardware. These requirements apply to all M-MIS equipment.

6.2.2 General

Section 6.2.2 of Chapter 10 states that the control system will meet the common system and equipment requirements in Section 7 of Chapter 10 of the Evolutionary Requirements Document. It originally stated that the control system design will be integrated with the reactor systems control discussed in Section 7 and that reactor control and power generation control require an overall integrated approach. In its request for additional information dated April 10, 1990, the staff indicated that the requirement for integration appeared to conflict with the requirements for segmentation and asked EPRI to clarify its intentions in this matter. In a letter dated July 23, 1990, EPRI stated that the intent of this requirement is to ensure that the design efforts and evaluations are coordinated, not that the systems are integrated. EPRI committed to revise Section 6.2.2 to state that the control system design will be coordinated to provide for smooth overall plant control and that the strong interactions between these systems require a coordinated design approach. In the DSER for Chapter 10, the staff identified the coordination of reactor and power generation control systems as a confirmatory issue because of EPRI's commitment to revise the Evolutionary Requirements Document as stated above. The staff has verified that the revisions have been made; therefore, this DSER confirmatory issue is closed.

EPRI states that the control system monitoring will provide enough information to monitor performance trends.

Section 6.2.2.4 of Chapter 10 appears to repeat the intent of Section 6.2.2.2, but adds the requirement to maintain a 15-percent design margin.

EPRI states that upon reinstatement of power, the computers will "self-start", but the controlled non-safety systems will not start without operator action.

Instrument racks will be provided to facilitate maintenance and testing. Electrical wiring that needs external connections will be routed to a connector or terminal box to facilitate maintenance. The length of instrument sensing lines is to be minimized. The instrumentation and control (I&C) equipment is to be protected from potential hazards.

Instrument ranges will cover system operating ranges with margin. Normal operating conditions will normally be shown as midscale on the instrumentation. Analog signals will be current inputs of differential voltage.

Section 6.2.2.13 of Chapter 10 states that instrument setpoint drift will not cause a violation of technical specification limits. The guidance that is provided includes Regulatory Guide 1.105, "Instrument Setpoints for Safety Related Systems," and Instrument Society of America 67.15, Draft-RP 67.04, Part II, "Methodology for the Determination of Setpoints for Nuclear Safety Related Instrumentation."

EPRI states that all equipment will be inherently free from electromagnetic inference (EMI) and will not broadcast EMI, or shielding and isolation will be provided. This is acceptable. The staff has concerns in the EMI area because of the extensive use of electronics and computers. This is an area that requires emphasis during the design phase. In its request for additional information dated April 10, 1990, the staff indicated that EPRI should provide additional implementation guidance in Section 6.2.2.14 of Chapter 10. In a letter dated July 23, 1990, EPRI stated that it is the designer's responsibility to demonstrate that this requirement is met. This may be done through shielding, restriction of communication devices, and testing of equipment. The staff concludes that this requirement does not violate NRC regulations and is, therefore, acceptable. However, restriction of communication devices should not prevent compliance with 10 CFR 73.55. NRC Information Notice 83-83 states: "As newer plants are built that use more solid state equipment...more cases of RFI [radiofrequency interference] by portable radio transmitters are likely to result.... If plant operations make the use of portable radio transmitters near RFI-sensitive equipment either necessary or likely in an emergency, then administrative prohibitions are not adequate and the licensee should consider hardware fixes." The staff will address issues associated with EMI during its review of an individual application for FDA/DC.

An acceptable method of shielding and grounding is provided in IEEE 1050-1989, "IEEE Guide for Instrumentation and Control Equipment in Generating Stations," but this standard is not referenced in the Evolutionary Requirements Document. In the DSER for Chapter 10, the staff concluded that this reference should be added and identified this as an open issue. In its response dated January 28, 1992, to a request for additional information dated May 17, 1991, EPRI stated that IEEE 1050-1989 had been added to Section 6.2.9 of Chapter 10, Revision 1. This is acceptable; therefore, this DSER open issue is closed.

EPRI states that the design will follow the guidance of DOD-HDBK-263, "Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment." The staff agrees with the need to address electrostatic discharge in the design and concludes that this is an acceptable reference.

Section 6.2.2.16 of Chapter 10 states that M-MIS equipment located outside the containment will be capable of operating between 40 °F and 120 °F. The I&C equipment will operate between 10- and 95-percent (noncondensing) humidity and at a maximum wet bulb temperature of 95 °F. EPRI states that operation between 60 °F and 105 °F will be used for reliability and availability assessment. The heating, ventilating, and air conditioning system (HVAC) will be designed to provide the required environment.

Section 6.2.2.17 of Chapter 10 states that the equipment will be designed to operate properly when exposed to the expected variations of voltage and frequency. The margins specified by IEEE 323-1974, (+/- 10-percent voltage and +/-5-percent frequency) are included in this requirement. Power conditioners can be used where needed. Because the newer computer-based equipment is particularly sensitive, the staff considers surge withstand capability to be an area that requires increased emphasis during the design phase. EPRI states that the M-MIS will be designed to protect against electrical noise and surges. Sections 6.2.2.17, 6.2.2.18, 6.2.8.1, and 6.2.8.3 specify M-MIS equipment performance requirements when operating under a range of various power supply system variations and perturbations.

In the DSER for Chapter 10, the staff concluded that EPRI should include a requirement that the designer develop a comprehensive specification pertaining to the interface between the M-MIS equipment and the external power supply systems that support it to ensure their compatibility. It identified compatibility between M-MIS equipment and its external power supply systems as an open issue. In its response dated January 28, 1992, EPRI stated that it would add requirements as stated above. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will evaluate compatibility between M-MIS equipment and its external power supply systems during its review of an individual application for FDA/DC.

EPRI states that the designer will select equipment to minimize the need for power and HVAC and will provide for the replacement or repair of equipment that is not expected to last for 60 years as part of the design. Large instrumentation and control (I&C) systems will be preassembled and will be designed so that circuit cards and microprocessor modules can be replaced when the channel is in bypass.

EPRI states that hazardous high-voltage areas will be labeled and shielded. This is acceptable. However, specific conformance with the National Electrical Code or Occupational Safety and Health Administration regulations is outside the scope of this review.

Section 6.2.2.24 of Chapter 10 states that signal validation will be performed on all critical safety, control, and plant availability systems. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide information on the methods to be used to meet this requirement. By letter dated July 23, 1990, EPRI responded that it was not the intent of the Evolutionary Requirements Document to provide such detailed design requirements. Therefore, the staff will evaluate signal validation methodology during its review of an individual application for FDA/DC.

EPRI requires that the I&C equipment be designed to perform diagnostics and troubleshooting down to the lowest replaceable circuit board or module level. The diagnostics and testing will be designed so that the equipment can be tested in place. Power outlets will be provided at all local stations to facilitate maintenance with appropriate precautions for electrical separation.

Cabinets will have permanently installed lighting. This should aid technicians performing diagnostics, repairs, and troubleshooting and is acceptable.

6.2.3 Computer Systems

Section 6.2.3 of Chapter 10 states that the hardware and software used throughout the plant will be standardized as much as practicable. The designer will specify the design life of the equipment and provide for replacement as needed. All equipment will be maintained under configuration management control.

System testing and validation will be performed with the software and hardware totally integrated. Integrated testing and validation is required and will be documented. The staff concludes that this is a good design practice and is, therefore, acceptable.

Section 6.2.3.6 of Chapter 10 states that the M-MIS designer will evaluate and establish the need for redundancy and diversity of computer and peripheral equipment. In the rationale, EPRI notes that the designer can perform a reliability analysis of the equipment and establish the need for redundancy and diversity. EPRI states that diversity may not be practicable because diversity and standardization are sometimes mutually exclusive. The staff believes, however, that a reliability analysis may not be an acceptable substitute for redundancy or diversity determinations in safety systems because of common-mode-failure concerns. It discusses this further in Section 6.1.6 of this chapter.

EPRI states that the maintenance and development hardware will be supplied to the utility. The software and hardware licenses and warranties from the equipment vendors as well as documents and training credits obtained from vendors will be delivered to the utility.

Computer-based systems will be provided with a battery-backed calendar clock. In the DSER for Chapter 10, the staff stated that EPRI should consider including a requirement that the designer include an alarmed self-diagnostic feature on the clock update to verify battery conditions for systems supporting important functions and identified this as an open issue. In its response dated January 28, 1992, EPRI stated that it would add a requirement that battery-backed calendar clocks have self-diagnostic features to verify the battery conditions for systems supporting important functions. The staff finds this acceptable. Therefore, this DSER open issue is closed.

The auctioneered power supplies will be designed so that maintenance and replacement of a power supply can be accomplished without disrupting the system.

6.2.4 Switches

Section 6.2.4 of Chapter 10 applies to the various types of switches used through the plant, including proximity, contact, level, pressure, and position switches.

EPRI states that the designer will specify the accuracy and repeatability requirements for each type of switch. Section 6.2.4.2 of Chapter 10 states that the designer should encourage the use of integrated logic for switches to simplify operator information. The designer will decide the use of wet or dry contacts. The designer will specify the design life for each switch, and the switch will be qualified for that lifespan.

The designer will consider intelligent logic design to detect switch failure. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide its rationale regarding the additional hardware and software complexity and failure modes versus the improved switch-failure detection. By letter dated July 23, 1990, EPRI responded that it would revise Section 6.2.4.5 to require the designer to evaluate the tradeoff between the use of intelligent switch logic and hardware and software complexity and switch failure modes. In the DSER for Chapter 10, the staff identified this issue as a confirmatory issue. The staff has verified that the revisions have been made; therefore, this DSER confirmatory issue is closed.

EPRI states that switches will have provisions for testing, will be modular, and will be designed to permit position adjustment.

6.2.5 Sensors

Section 6.2.5 of Chapter 10 includes the requirements for various types of sensors, including temperature, pressure, acoustic, optical, vibration, flow, neutron, radiation, level, current, and voltage sensors.

Originally, Section 6.2.5.1 of Chapter 10 stated that reactor coolant system temperature sensors will either be thermowells welded into the piping or temperature probes such as resistance temperature detectors (RTDs) strapped to the exterior of the piping. Direct-immersion sensors will not be used. The control system will be designed to accept the slower response times. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide additional justification that this requirement was not a reduction in the capability and safety of previous designs. By letter dated July 23, 1990, EPRI responded that the provision for rapidly replacing the sensors will improve the overall monitoring capabilities. The staff concludes that this response is acceptable.

EPRI states that the designer will select the temperature-measuring devices and will consider multiple sensors and specify their use in areas where there may be thermal stratification. The staff concludes that this is a good design practice and is, therefore, acceptable.

The designer is responsible for specifying the accuracy and repeatability requirements and the calibration accuracy requirements.

The designer is allowed to use flow nozzles, averaging Pitot tubes, and vortex shielding.

The designer will consider the use of temperature devices other than RTDs and thermocouples. The requirement only calls for consideration of the devices and seems to imply that they are preferable but does not require them. The staff agrees that devices should be considered.

Section 6.2.5.8 of Chapter 10 states that sensors will be qualified for the full range of use. It originally stated that the designer was allowed to qualify by analysis. In the rationale, EPRI also originally stated that testing was the desired qualification method and there was a finite risk associated with qualification by analysis. In its request for additional information dated April 10, 1990, the staff stated that it generally does not accept qualification by analysis rather than by test. By letter dated

July 23, 1990, EPRI responded that it would revise this section to remove the reference to analysis so that the requirement will simply state that the device will be qualified. In the DSER for Chapter 10, the staff identified the qualification of sensors as a confirmatory issue. The staff has verified that the revisions have been made; therefore, this DSER confirmatory issue is closed.

EPRI states that sensors will have provisions for connections to micro-processor-based test equipment.

Section 6.2.5.10 of Chapter 10 states that design provisions will be included to minimize leaving sensor isolation valves aligned in the incorrect position after calibration. In the DSER for Chapter 10, the staff stated that EPRI did not provide specific guidance for this requirement. The staff concluded that EPRI should provide such guidance and identified guidance on the position of sensor isolation valves as an open issue. In its response dated January 28, 1992, EPRI stated that it would add a requirement to minimize leaving sensor isolation valves aligned in the incorrect position after calibration by requiring software logic and valve position indication to prohibit the operation until valves are sequenced correctly. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed.

EPRI states that local logic modules will be replaceable and that sensors will have provisions for either field or bench calibration.

Section 6.2.5.13 of Chapter 10 originally stated that sensors will have no undetectable failure mode. In the DSER for Chapter 10, the staff concluded that EPRI should clarify this section to address the loss-of-oil concerns associated with capacitance-type pressure sensors. Excessive drift in a setpoint is a failure mode that may not be detected until calibration. This requirement could be interpreted to require that all sensors have on-line diagnostics and calibration. The staff identified capacitance-type pressure sensors as an open issue.

In its response dated January 28, 1992, EPRI stated that it would revise Section 6.2.5.13 (Volumes II and III of the Requirements Document) of Chapter 10 to require that the sensor have no undetectable failure mode to the extent practicable. It would also require the plant designer to identify those sensors that cannot meet this requirement and justify why on-line diagnostics and calibration are not possible. This is acceptable because it does not conflict with current regulatory requirements. Therefore, this DSER open issue is closed. However, the staff will evaluate this item in detail during its review of an individual application for FDA/DC.

EPRI states that diversity will include the principle of operation as well as function to minimize common-mode failures. The staff discusses diversity and common-mode failures in Section 6.1.6 of this chapter.

6.2.6 Isolation Devices

Section 6.2.6 of Chapter 10 requires that the digital and analog isolation devices meet Regulatory Guide 1.75. Because it does not conflict with regulatory requirements, this requirement is acceptable. However, additional requirements concerning the adequacy of isolation devices must be met before the staff can approve a specific design.

Section 6.2.6.2 of Chapter 10 states that fiberoptic cable is an acceptable isolator. The staff agrees that the cable itself has inherent electrical isolation capabilities that do not need to be tested or analyzed further. However, the designer must verify that independence and isolation are not compromised by the communication software and protocol that may be used in implementing the link. Qualification of the hardware system is also necessary to ensure that, for example, metallic fiberoptic cable sheaths provided for mechanical protection do not introduce ground loops between equipment requiring isolation. In its request for additional information dated April 10, 1990, the staff asked EPRI to address the compliance of fiberoptic cable with General Design Criteria 3, 21, 22, and 24 of Appendix A to 10 CFR Part 50 and Regulatory Guide 1.75. By letter dated July 23, 1990, EPRI responded that it would revise this section to include a requirement that the designer comply with these regulations and regulatory guidance. Although specific criteria are not provided, conformance with the requirements is acceptable.

In the DSER for Chapter 10, the staff identified fiberoptic standards as a confirmatory issue. The staff has verified that Chapter 10 contains these requirements and that the revisions have been made. Therefore, this DSER confirmatory issue is closed.

EPRI states that the designer is responsible for selecting the isolators. The various types of isolators listed in Section 6.2.6.3 of Chapter 10 are generally acceptable to the staff but must be shown, by testing, to isolate under maximum credible fault conditions in accordance with IEEE 279. The NRC minimal acceptance review criteria for isolation devices are the following:

- For the type of device used to accomplish electrical isolation, the specific testing performed to demonstrate that the device is acceptable for its application shall be described. This description should include elementary diagrams when necessary to indicate the test configuration and the application of the maximum credible faults to the devices.

- Data shall be supplied to verify that the maximum credible faults applied during the testing were the maximum voltage and current to which the device could be exposed, and the method used to define the maximum voltage and current shall be documented.

- Data shall be supplied to verify that the maximum credible fault was applied to the output of the device in the transverse mode (between signal and return) and that other faults, such as open and short circuits, were considered.

- The pass/fail acceptance criterion shall be established before testing and documented.

- The seismic and environmental qualification for each device shall be demonstrated.

- The measures taken to protect the safety systems from electrical interference (e.g., EMI, electrostatic coupling, and crosstalk) shall be described.

- The isolators used to separate safety systems from non-safety systems shall be powered by the Class 1E power supply.

In the DSER for Chapter 10, the staff stated that the Evolutionary Requirements Document should be revised to list these criteria and identified minimal acceptance review criteria for isolation devices as an open issue. In its response dated January 28, 1992, EPRI stated that a requirement will be added to require that an acceptable level of isolation be achieved by testing the device under maximum credible fault conditions in accordance with IEEE 279. The staff agrees with the testing requirement and finds it acceptable because it does not conflict with current regulatory requirements. Therefore, this DSER open issue is closed. However, the staff will evaluate this item during its review of an individual application for FDA/DC.

EPRI states that the analog isolators will not degrade the accuracy of the system below acceptable levels and will not degrade significantly over time. The devices will provide at least 80 dB common-mode rejection.

6.2.7 Valves (Instrumentation and Control Features)

Section 6.2.7 of Chapter 10 states that the valve operational module and the position indication module will be separate to permit the replacement of one without the other. The logic and position modules are to be standardized.

Section 6.2.7.3 of Chapter 10 originally specified that the Class 1E motor-operated valves will have their thermal overloads bypassed continually in accordance with Regulatory Guide 1.106, "Thermal Overload Protection for Electric Motors on Motor Operated Valves," and the only time the overload bypass will be removed is during maintenance and testing of valves. This requirement appeared to conflict with a requirement in Section 6.5.2 of Chapter 11 of the Evolutionary Requirements Document that specifies that bypassing features for the purpose of restricting operator protection will normally not be provided. In a letter dated August 2, 1990, the staff asked EPRI to clarify this apparent discrepancy and to provide some examples of thermal overload system designs that would satisfy this requirement. In a letter dated October 12, 1990, EPRI stated that it would revise Section 6.2.7.3 of Chapter 10 to include Regulatory Guide 1.106 and IEEE 741. This is consistent with the requirements in Section 6.5.2 of Chapter 11 of the Evolutionary Requirements Document. In the DSER for Chapter 10, the staff concluded that the change was acceptable and identified this as a Confirmatory issue. It has confirmed that the change was acceptably incorporated into the Evolutionary Requirements Document. Therefore, this DSER Confirmatory issue is closed.

Section 6.2.7.3 of Chapter 10 also specifies required characteristics for motor-operated valves. NRC Branch Technical Position (BTP) ICSB 18 (PSB), "Application of the Single Failure Criterion to Manually-Controlled Electrically-Operated Valves," in Appendix A to Section of the SRP, provides guidance on the design and acceptability of manually controlled electrically operated valves when it is necessary to remove power from them in order to meet the single-failure criterion. In a letter dated August 2, 1990, the staff asked EPRI to reference the positions in BTP ICSB 18 (PSB) in Section 6.2.7.3 of Chapter 10 and to stipulate that the number of valves that require power removal in order to meet the single-failure criterion should be minimized. The staff indicated that the Evolutionary Requirements Document should require that this provision be limited to only those situations where design of the piping system to eliminate the need to remove power from the valve would result in a less safe design than the design that requires power removal. In a letter dated October 12, 1990, EPRI stated that Table B.1-2 of Appendix B to Chapter 1 of the Evolutionary Requirements Document will state that the designer will comply with BTP ISCB 18 (PSB). In addition, EPRI identified proposed changes to Section 6.2.7.3. In the DSER for Chapter 10, the staff concluded that the proposed changes were acceptable and identified this as a confirmatory issue. The staff has verified that these changes have been made; therefore, this confirmatory issue is closed.

Section 6.2.7.3 of Chapter 10 originally gave NAMCO as an example of an acceptable limit switch. In its request for additional information dated April 10, 1990, the staff asked if a list of equipment acceptable to EPRI would be included in the Evolutionary Requirements Document. By letter dated July 23, 1990, EPRI responded that it did not intend to list acceptable devices, that the referenced switch was an example, and that it would remove the NAMCO reference. In the DSER for Chapter 10, the staff identified this as a confirmatory issue. The staff has verified that the reference to NAMCO has been deleted from Section 6.2.7.3 of Chapter 10; therefore, this confirmatory issue is closed.

Section 6.2.7.4 of Chapter 10 states that power-operated valves will have local indication and manual valves will have security locking devices when needed.

In DSER for Chapter 10, the staff identified manual valve position indication as a confirmatory issue because EPRI had committed in a letter dated October 12, 1990, to add a sentence to Section 4.4.4 of Chapter 10 to clarify that control room indication of misaligned manual valves is not prohibited by this requirement. The staff has verified that Section 4.4.4 of Chapter 10 includes a revision that satisfies EPRI's commitment; therefore, this DSER confirmatory issue is closed. The staff discusses manual valve position indication in Appendix D to this chapter.

EPRI originally stated that valve designs will have provisions for detecting internal and external leakage. In its request for additional information dated April 10, 1990, the staff asked EPRI to describe the methods intended to detect internal and external leakage for all valves. By letter dated July 23, 1990, EPRI responded that it would revise Section 6.2.7 of Chapter 10 to require that only the critical valves, as determined by the designer, be monitored. In the DSER for Chapter 10, the staff identified internal and external leakage detection as a confirmatory issue. The staff has verified that the revisions have been made; therefore, this DSER confirmatory issue is closed.

EPRI states that any special tools for diagnostics or calibration will be provided to the utility.

EPRI states that failure modes will be selected to allow the plant to remain at power. The staff will evaluate the failure modes selected during its review of an individual application for FDA/DC.

6.2.8 Instrumentation and Control Power Supplies

Section 6.2.8 of Chapter 10 states that the M-MIS equipment will function when exposed to the expected variations of input voltage and frequency. The staff discusses this topic in greater detail in Section 6.2.2 of this chapter.

In the DSER for Chapter 10, the staff concluded that EPRI should specify in Section 6.2.8.2 the battery and dc system voltages that should be included in the M-MIS equipment design and identified this as an open issue. EPRI revised Section 6.2.8.2 to require that the M-MIS equipment be designed to operate over a dc input voltage range, taking into account battery voltage variations within design limits as determined by Section 7.2.7 of Chapter 11. Section 7.2.7 of Chapter 11 contains sufficient information to properly characterize the dc system operating voltage limits that must be considered to ensure acceptable operation of M-MIS equipment. Therefore, this DSER open issue is closed.

Section 6.2.8.3 of Chapter 10 indicates that the power inputs will meet appropriate standards for surge suppression. However, it does not specify which standards must be met. In Section 6.2.2.18, a comparable requirement references IEEE C37-90.1-1989 and IEEE C62.41-1980. In the DSER for Chapter 10, the staff concluded that EPRI should specify the surge limits that apply to this section and identified this as an open issue. Section 6.2.8.3 was revised to reference IEEE C62.41-1980, "IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits," with regard to the surge limits; therefore, this DSER open issue is closed.

EPRI states that overcurrent protection will be provided and that subsystem dc supplies will be provided with overvoltage and overcurrent protection.

Power source input connection points will be within an enclosure and readily accessible. DC power within an equipment bay will be supplied by dc power supplies within the same bay. Cables from the power supplies will be sized for the loads.

Section 6.2.8.9 of Chapter 10 originally stated that non-Class 1E equipment powered from Class 1E power will have all associated instrumentation and controls powered from the same Class 1E division. This section appeared to conflict with the requirement of Section 2.3.9 of Chapter 11 of the Evolutionary Requirements Document, which states that the design of the plant electric power distribution systems will be suc that the non-safety-related circuits are not connected to safety circuits or power sources. In a letter dated April 10, 1990, the staff asked EPRI to change Section 6.2.8.9 to specify that non-Class 1E system instrumentation and controls will only be connected to non-Class 1E power supplies and distribution systems and will not be connected to Class 1E power supplies or distribution systems. In a letter dated October 12, 1990, EPRI proposed revisions to Section 6.2.8.9 to address the staff's concern. In the DSER for Chapter 10, the staff concluded that the proposed revisions were acceptable and identified this as a confirmatory issue. The staff has verified that the proposed changes have been made; therefore, this confirmatory issue is closed.

EPRI states that if any part of a function is powered from an uninterruptible power supply bus (UPS), the entire function will be powered from a UPS bus.

Section 6.2.8.11 of Chapter 10 originally stated that a distinct indication of loss of power will be provided. In its request for additional information dated April 10, 1990, the staff noted that the requirement in this section that an indicator read its lowest position on loss of power appeared to be inconsistent with the requirements of Section 6.2.2.12. Section 6.2.2.12 discouraged this requirement because downscale failure cannot be distinguished from a true zero reading. By letter dated July 23, 1990, EPRI responded that it would revise Section 6.2.8.11 as well as Sections 6.2.2.12 and 4.4.? of Chapter 10 to include a requirement to differentiate between power supply failures and other failures. In the DSER for Chapter 10, the staff identified failure indication differentiation as a confirmatory issue. The staff has verified that the revisions have been made; therefore, this DSER confirmatory issue is closed.

EPRI states that if equipment needs power other than that normally supplied, the equipment will be supplied with its own power supply.

6.2.9 Grounding

Section 6.2.9.1 of Chapter 10 states that protective power grounds will be routed separately from signal grounds. Means will be provided to ground all equipment. A protective ground will be provided for all cabinets where the operating voltage is more than 50 volts. The staff concludes that this is acceptable. However, because of future upgrades and the use of portable testing and maintenance equipment, EPRI may wish to consider grounding all cabinets.

The grounds will be connected so that one piece of equipment may be disconnected at a time without disconnecting other equipment. The staff concludes that this is a good design practice and is, therefore, acceptable.

EPRI states that a portable ground cable will be provided to ground out-of-service electrical equipment. Cabinet grounding will be provided.

Power supply common returns will be provided and grounded at one point to prevent ground loops. The staff concludes that this is acceptable. However, this is a method for reducing ground-loop problems and may not prevent ground loops, as noted in EPRI's rationale.

Section 6.2.9.2 of Chapter 10 states that wiring shields will be grounded separately from the circuit modules so that the modules can be removed without ungrounding the shield connection. In the DSER for Chapter 10, the staff concluded that this requirement was acceptable if the designer can demonstrate that the configuration is qualified for its electromagnetic interference/radiofrequency interference (EMI/RFI) environment. The staff concluded that EPRI should clarify this section to reflect this condition and identified EMI/RFI considerations for wiring shields as an open issue. In its response dated January 28, 1992, EPRI stated that in its response to the May 17, 1991, request for additional information, it had added the guidance in IEEE 1050-1989 to Section 6.2.9 of Chapter 10, Revision 3. The staff finds this addition acceptable. Therefore, this DSER open issue is closed. However, the general issue of how to demonstrate that the equipment is qualified for its EMI/RFI environment is a vendor- or plant-specific item.

Analog signals will be grounded at a single point. Instrumentation cable shields will be grounded at only one location. Shields will be terminated on terminal blocks adjacent to the signal wires. Section 6.2.9.2 of Chapter 10 provides guidance on shield-grounding methods to minimize leakage between signals and shields; however, it does not reference specific grounding standards. In the DSER for Chapter 10, the staff concluded that the Evolutionary Requirements Document should reference these standards and identified the use of qualified isolators for wiring shields as an open issue. In its response dated January 28, 1992, EPRI stated that qualified isolators between systems within safety channels were not a requirement and clarified that the intent of this section was to use isolation buffers in the design to prevent ground loops. The staff agrees with this requirement as clarified; therefore, this DSER open issue is closed.

EPRI states that there will be sufficient isolation ground between system grounds to prevent ground loops. Instrument grounds will be designed to minimize the effects of common-mode voltage levels. The signal connections between systems will have isolators. In the DSER for Chapter 10, the staff concluded that EPRI should clarify if this meant qualified isolators between systems within a safety channel and identified this as an open issue. EPRI has revised Section 6.2.9 to clarify that these isolators are for ground isolation and are not to be "qualified" as those used between safety systems. Therefore, this DSER open issue is closed.

EPRI states that the signal grounding scheme for assemblies, subassemblies, and subsystems will use a "branching" scheme to minimize ground loops. Instrument ground connections will be corrosion resistant. The communication systems will not [illegible] the instrument ground bus.

6.2.10 Electrical Penetrations and Seals

Section 6.2.10 of Chapter 10 states that the instrumentation and control (I&C) signals will not be degraded if penetration connectors are used. Splices are permitted but are to be avoided, especially for fiberoptic cables. Penetrations will be provided with spare connectors. The effects of EMI/RFI from other electrical penetrations will be considered in the design of the I&C penetrations.

6.2.11 Cables, Fiberoptics, and Raceways

Section 6.2.11 of Chapter 10 states that the designer will determine the need for spare conductors. The cables will be color coded. Conductors will be identified in accordance with Insulated Power Cable Engineers Association S-61-402. Twisted shielded pairs will be color coded in accordance with ANSI C96.1.

The designer will select or establish internal panel wiring standards. Preassembly of instrument and control cables is encouraged. Low-voltage cables will be separated from power cables. Power cables will be shielded, and the shields will be grounded.

Section 6.2.11.2.4 of Chapter 10 states that internal panel wiring will meet the following separation criteria:

- AC and DC wiring will be separated.
- Instrumentation wiring will be separate from control or power.
- Separation between Class 1E circuits and non-Class 1E circuits and redundant Class 1E circuits will be in accordance with IEEE 384-1974, NRC Regulatory Guide (RG) 1.75, and NRC Branch Technical Position CMEB 9.5-1 (SRP Section 9.5.1).
- There will be 6-inch separation between redundant channels or that which can be established by analysis.
- Conduit openings will be sealed.

EPRI states that the minimum bend radius of the fiberoptic cable will be considered in designing the cable raceway.

6.2.12 Field Termination and Splices

Section 6.2.12 of Chapter 10 states that field terminations and splices will be positively secured while being easy to disconnect. Although the staff agrees with the rationale that the designer has the option to consider termination methods other than ring lugs, the disadvantage of time-consuming field wire terminations with ring lugs should not be considered an equal tradeoff with the security of termination that they provide. Terminal identification will be provided. In the DSER for Chapter 10, the staff concluded that the requirements in Section 6.2.12 should be modified to note that splices will not be allowed in raceways in accordance with Position C.9 of RG 1.75, Revision 2. This modification was recommended in order to avoid any misunderstanding that the splice requirements provided in this section would allow splices in raceways in violation of the RG 1.75 position and was identified as an open issue in the DSER. In its letter dated January 28, 1992, EPRI stated that the requirements of Section 2.6.3.6 of Chapter 11 had been changed to address this issue and Table B.1-2 of Appendix B to Chapter 1 indicates that the ALWR will comply with RG 1.75, Revision 2. EPRI stated that an additional requirement on field wire terminations and splices was not necessary. Section 2.6.3.6 of Chapter 11 has been revised to require that cable splices be prohibited unless protected by junction boxes specifically intended for that purpose. The staff agrees with EPRI that this provision, together with the commitment to comply with RG 1.75, Revision 2, clearly indicates that splices in raceways will not be allowed, and no further requirements or clarifications are necessary in Section 6.2.12 of Chapter 10. Therefore, this DSER open issue is closed.

6.3 <u>Common Control System Requirements</u>

6.3.1 Definition

Section 6.3.1 of Chapter 10 of the Evolutionary Requirements Document defines the common requirements for the design, selection, and installation of specific M-MIS control systems. EPRI states that all control systems required for operation and maintenance of the plant are included in the scope of this section, which addresses the design, performance, availability/operability, testability and qualification, and maintainability and serviceability requirements for this equipment.

6.3.2 Design Requirements

Section 6.3.2 of Chapter 10 states that all safety-related control system software will be retained in programmable read-only memory or on battery-backed read-only memory chips. Constant values, such as setpoints, will be maintained in nonvolatile memory.

EPRI states that software interface is discouraged between safety-related and non-safety-related systems but is allowed if the designer can demonstrate that isolation is provided.

When evaluating stability and response rates, EPRI specifies that the designers should consider the following:

- plant and equipment nonlinearities that change with the operating point (valves, plant processes, etc.)

- time delays

- the effect of sample rate and resolution

- the effect of sensing subsystem components

- the effect of environmental extremes and process conditions

The designer will define and design the systems that will remain in the known safe state following restoration of power after a loss of power. The staff concludes that this requirement is acceptable but will evaluate the specific systems and the restoration state during its reviews of individual application for FDA/DC.

6.3.3 Performance Requirements

Section 6.3.3 of Chapter 10 specifies that digital control algorithms will include an anti-windup feature when needed. Transfers between manual and automatic control will be bumpless.

The settings for all control parameters will provide a resolution and accuracy of 1 percent of the full-scale adjustment range. The staff concludes that this is generally acceptable, but the designer should verify that there are no conditions for which more stringent requirements are warranted. The staff will address this issue during its review of an individual application for FDA/DC.

Section 6.3.3.4 of Chapter 10 provides requirements to ensure that the designer will specifically address aliasing problems with sample data. However, the reference to EPRI contractor work to establish the requirements in this section needs to be completed. In the DSER for Chapter 10, the staff concluded that EPRI should update or clarify the requirements for this section and identified requirements for signal reconstruction as an open issue. In its response dated January 28, 1992, EPRI stated that in response to a request for additional information dated May 17, 1991, it had updated Section 6.3.3.4 of Chapter 10, Revision 3, to clarify the addressing of aliasing problem with sample data. The clarification is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed. However, the staff will evaluate this item during its review of an individual application for FDA/DC.

Section 6.3.3.5 of Chapter 10 indicates that computers that have direct protection or control functions will not have interrupts. Section 6.3.3.7 states that functions are to be prioritized so that a protective function is the highest priority. These sections appear to conflict. In general, the staff considers that the use of interrupts in safety systems should be avoided and identified the use of interrupts as an open issue in the DSER for Chapter 10. The staff concluded that EPRI should revise the Evolutionary Requirements Document to more clearly state under what conditions interrupts are allowed. In its response dated January 28, 1992, EPRI stated that requirements will be added to require the use of interrupts if it improves system reliability or is required to perform protective functions or other functions promptly. This is acceptable because it does not conflict with current regulatory requirements. Therefore, this DSER open issue is closed. However, the staff will evaluate this item during its review of an individual application for FDA/DC.

EPRI states that the designer will consider the startup testing requirements and will design the instrumentation and control (I&C) system to minimize special setups and equipment.

6.3.4 Availability/Operability

For non-safety-related systems, Section 6.3.4 of Chapter 10 stipulates the use of reliable components instead of redundant equipment to achieve reliability. In the DSER for Chapter 10, the staff stated that although this requirement was not in violation of NRC requirements, a requirement encouraging redundancy to reduce challenges to safety systems in addition to the use of reliable components would be more appropriate and identified redundancy of safety systems as an open issue. In its response dated January 28, 1992, EPRI stated that the intent of this section was to provide a perspective on the approach the plant designer should use for non-safety-related control functions to meet the requirements of Chapter 1 and Chapter 10, Section 3.5, of the Evolutionary Requirements Document. This is acceptable because it does not conflict with current regulatory requirements. Therefore, this DSER open issue is closed.

EPRI states that signals from other systems may be used in non-safety-related control systems to enhance reliability. In addition, the control function may be redistributed to another computer if a computer fails, thereby providing some redundancy. The staff concludes that this requirement is acceptable if it applies only to non-safety-related systems. The designer will have to evaluate safety-related systems to ensure that implementation of this EPRI requirement does not violate NRC regulations.

The I&C system will be a distributed system with local control. Central computers will be used only for monitoring. The staff concludes that this configuration is preferred and that it is, therefore, acceptable.

6.3.5 Testability and Qualification

Section 6.3.5 of Chapter 10 states that the designer will establish the criteria for determining which of the redundant systems will be used.

6.3.6 Maintainability/Serviceability

Section 6.3.6 of Chapter 10 states that the maintenance interface will provide the capability to access diagnostic, calibration, and other maintenance aids. All system inputs and outputs will be accessible. Maintenance activities will be indicated in the main control room.

6.4 Conclusion

The staff concludes that the items the requirements in Section 6 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are, therefore, acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

7 OVERALL PLANT, REACTOR, AND REACTOR COOLANT SYSTEMS M-MIS REQUIREMENTS

7.1 Purpose and Scope

Section 7.1 of Chapter 10 of the Evolutionary Requirements Document states that Section 7 provides the requirements for the M-MIS that will monitor and control the overall power production of the plant as well as the reactor and reactor coolant system.

EPRI specifies that the M-MIS for the specific systems discussed in this section will be integrated and coordinated with the M-MIS for other plant systems.

7.2 General Requirements for Overall Plant, Reactor, and Reactor Systems Group M-MIS

Section 7.2.1 of Chapter 10 of the Evolutionary Requirements Document describes how the functions of the M-MIS are to be initially allocated. EPRI states that the M-MIS will provide for the monitoring and control of the overall process of producing energy in the reactor core to the delivery of electricity to the grid and removal of waste heat. The M-MIS will monitor neutron flux and adjust the reactivity. Core outlet temperatures (PWRs) will also be monitored. The M-MIS will monitor and control the reactor coolant system pressure and will also monitor and control the chemical and volume control system (PWRs) and the reactor water cleanup system (BWRs). Chemistry will be monitored using the process sampling system M-MIS, and reactor coolant leakage will be monitored using the reactor coolant leak detection system M-MIS. The M-MIS will monitor and control the removal of reactor core heat and the steam production process.

Section 7.2.2 of Chapter 10 states that the system physical boundaries are defined in Chapters 3 and 4 of the Evolutionary Requirements Document. The boundaries for the M-MIS will be the same as those for the primary systems and will also include the M-MIS hardware and software.

Section 7.2.3 of Chapter 10 states that the designer will use consistent monitoring and control design strategies. The staff concludes that this is acceptable, but notes that this consistency should not result in the elimination of the consideration of diversity.

The M-MIS will include monitoring and control of systems for startup and shutdown: Local operation is preferred over main control room operation when possible. EPRI states that automation of the functions to reduce operator burden is allowed, if justified, but is not encouraged because automation would increase the complexity of the plant.

During normal operations, the M-MIS controlling this group of systems will be automated or otherwise provide for continuous operation without repeated operator tasks. Occasional tasks do not require automation.

EPRI states that automatic reconfiguration of systems will be provided when needed for personnel or equipment protection or when required because of safety system actuation. However, Section 7.2.3.3 of Chapter 10 does not address the selection process for determining when automatic or manual control is to be used. In the DSER for Chapter 10, the staff concluded that EPRI should provide such guidance and identified the selection of automatic or manual control as an open issue. In its response dated January 28, 1992, EPRI stated that the selection of automatic or manual control is based on specific evaluations and a list of the minimum items that must be considered is given in Section 3.4.3 of Chapter 10. EPRI also stated that the analysis of functions and tasks will allocate the functions between automatic and manual control. This is acceptable because it does not conflict with current regulatory guidance; therefore, this DSER open issue is closed.

EPRI states that return of a system to its initial configuration after an automatic reconfiguration will normally require manual initiation but can be automated when justified. Any automatic return to an original configuration will require operator notification.

The M-MIS will normally be tested on line only at the direction of the operator. The testing should be automated after it is initiated by the operator. Other testing requirements are evaluated by the staff in Section 3.6 of this chapter.

Section 7.2.4 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS designer will integrate and coordinate the systems covered by this section. As noted in the rationale, the Evolutionary Requirements Document specifically avoids providing any specific guidance as to how this will be best accomplished. Thus, the M-MIS designer is not constrained by current practice. The staff concludes that this is acceptable. However, the Evolutionary Requirements Document does specifically state that EPRI prefers proven technology.

The staff's evaluation of the human factors aspects of this section is provided in Appendix D to this chapter.

7.3 <u>Overall Plant M-MIS</u>

Section 7.3.1 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS functional goal is to efficiently and effectively deliver electricity to the grid. Section 7.3.2 of Chapter 10 originally stated that the M-MIS will enable the utility load dispatcher to adjust reactor power directly. In its response dated July 23, 1990, to a request for additional information dated April 10, 1990, EPRI stated that the intent of this requirement is to allow the load dispatcher to change power level within a range selected by the operators. In the DSER for Chapter 10, the staff concluded that this section could be misinterpreted as allowing the manipulation of reactor controls by personnel other than licensed unit operators and identified this as an open issue. Controls that directly affect the power of the reactor can only be manipulated by licensed operators. Apparatus and mechanisms other than controls that directly affect reactor power can be manipulated only with the consent and knowledge of the licensed operator at the controls. Economic power generation systems in use today allow the utility load dispatcher to initiate reactor power changes, but these changes are actually made by the digital data acquisition and control system (DDACS). The DDACS controls the power change rate by "manipulating" the reactor controls. This system is under the cognizance of the licensed unit operator at all times, and power changes by the load dispatcher are first approved by the licensed un operator. In Revision 4, EPRI revised Section 7.3.2 by removing the word "directly" to prevent possible misinterpretation of this requirement. Therefore, this DSER open issue is closed.

Section 7.3.3 of Chapter 10 states that the overall M-MIS will be coordinated with the M-MIS of other systems. Section 7.3.4 of Chapter 10 states that the M-MIS will provide the capability (1) to monitor the functions of all major components and the plant heat balance and (2) to determine if a change in plant operation setpoints would provide more efficient operation. The staff concludes that this is acceptable.

7.4 Neutron Monitoring System M-MIS

Section 7.4 of Chapter 10 of the Evoluti ary Requirements Document states that the neutron monitoring system M-MIS will provide the information needed to determine if the amount, rate of change, and distribution of fission energy are correct. The designer will determine the design of the monitoring strategy. The staff will evaluate the neutron monitoring system M-MIS during its review of an individual application for FDA/DC.

7.5 BWR Rod Control System M-MIS

Section 7.5 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the BWR rod control system will provide the monitoring and control necessary to position the control rods within acceptable limits. The designer will determine which functions of the normally manually controlled shutdown and startup control should be automated.

EPRI states that during the design process the functions and tasks involved in scram time testing will be evaluated and the need for automation to provide accurate and reliable results will be determined.

7.6 PWR Rod Control System M-MIS

Section 7.6 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR rod control system will provide the monitoring and control necessary to position the control rods within acceptable limits. The designer will evaluate any automated actions needed for the normal startup and shutdown functions. The staff concludes that this is acceptable.

7.7 BWR Reactor Coolant System M-MIS

Section 7.7 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the BWR reactor coolant system (RCS) will provide the monitoring and control necessary to

- adjust the reactivity
- maintain the RCS pressure within limits
- maintain RCS inventory
- remove core energy during normal operation and shutdown
- control steam production
- prevent unstable operation
- prevent overfilling

EPRI states that the M-MIS for the BWR RCS will normally be automatic but will provide for manual operation.

7.8 PWR Reactor Coolant System M-MIS

Section 7.8 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR RCS will provide the monitoring and control necessary to

- maintain pressure control
- maintain inventory control
- remove normal and shutdown core heat

EPRI states that the M-MIS for the PWR RCS will normally be automatic but will provide for manual operation.

7.9 PWR Chemical and Volume Control System M-MIS

Section 7.9 of Chapter 10 of the Requirements Document states that the M-MIS for the chemical and volume control system (CVCS) will provide the monitoring and control necessary to

- maintain the boron concentration
- maintain RCS inventory
- control water chemistry

EPRI states that the M-MIS for the CVCS will provide indication and control as described in Section 6.5 of Chapter 3 of the Evolutionary Requirements Document. The CVCS will be a non-safety-related system.

7.10 Process Sampling System M-MIS

Section 7.10 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the process sampling system will provide the control and monitoring necessary to obtain and evaluate samples from various fluid and gas systems. Sampling will be initiated manually and locally; however, operator aids will be provided. Interlocks will be provided to prevent sampling from affecting system availability. Repetitive monitoring will be automatic. If automatic sampling requires a system change that is also automatic, the change will be annunciated.

7.11 PWR Boron Recycle System M-MIS

Section 7.11 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR boron recycle system will provide the monitoring and control necessary to process and recycle the RCS water and will provide the necessary makeup water and boric acid.

7.12 BWR Reactor Water Cleanup System M-MIS

Section 7.12 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the BWR reactor water cleanup (RWCU) system will provide the monitoring and control necessary to remove reactor coolant, maintain proper inventory during operations, and maintain the reactor water chemistry. EPRI states that RWCU system operations associated with startup and shutdown will be performed in the main control room (MCR). Filter and demineralizer operations will be performed at stations outside the MCR. The RWCU system M-MIS will be capable of being monitored in the MCR. The designer will determine the operations that need to be controlled from the MCR.

The RWCU system will be automatically isolated if automatic monitoring detects a significant leak or if the standby liquid control system is initiated.

7.13 PWR Steam Generator System M-MIS

Section 7.13 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR steam generator system will provide the monitoring and control necessary for steam production for normal turbine operation and for certain decay heat removal operations.

Steam generator level control during startup will be automated and will include both startup and main feed pumps. Manual control will be provided. Normal level control as well as level control during planned or unplanned reactor and turbine trips will be automatic.

7.14 Reactor Coolant System Leak Detection M-MIS

Section 7.14 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for RCS leak detection will monitor the RCS leakage to ensure it is within acceptable limits. Because leakage from the RCS that cannot be specifically located may require plant shutdown, EPRI requires that the M-MIS reduce leakage data and present a summary of current estimated leak rates and other leakage indications that would help identify actual reactor coolant leakage. Several items are listed in the Evolutionary Requirements Document that may be used to identify the quantities and location of leakage. The staff has reviewed these items and, in the absence of specific criteria, concludes that they are acceptable.

The M-MIS for this system will be specifically designed so that the impact of plant and system transients on inventory is considered to avoid misleading leakage results.

7.15 Conclusion

The staff concludes that the requirements in Section 7 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are, therefore, acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

8 REACTOR PROTECTION AND SAFETY SYSTEMS M-MIS REQUIREMENTS

8.1 Purpose and Scope

Section 8.1 of Chapter 10 of the Evolutionary Requirements Document states that Section 8 provides the requirements for the M-MIS that will monitor and control reactor protection and safety systems.

The M-MIS for the systems addressed in Section 8 will be coordinated and integrated with the M-MIS for other plant systems.

8.2 General Requirements for Reactor Protection and Safety Systems Group M-MIS

8.2.1 Functions

Section 8.2.1 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the reactor protection system (RPS) and other safety systems will provide the monitoring and control necessary for those systems to carry out the required plant and system functions. EPRI divides the M-MIS functions into two categories: core-damage protection and core-damage mitigation. Section 1 of Chapter 10 states that the Evolutionary Requirements Document incorporates technological improvements. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide additional information to demonstrate that these were improvements and not merely changes. The staff also requested clarification of the level of safety of the instrumentation and control (I&C) systems as compared to that of previous designs. By letter dated July 23, 1990, EPRI indicated that it was not evident how to evaluate whether the designs of the I&C systems proposed in the Evolutionary Requirements Document were safer than previous designs. However, EPRI expects that the total system and operator interface will be substantially safer than that in current plants.

The M-MIS will provide the monitoring and control capability to limit the reactor energy so that core damage does not result. Since this is the basic goal of the existing RPS functions, the staff concludes that this requirement is acceptable.

Section 8.2.1 of Chapter 10 requires a safety-related M-MIS for reducing pressure in the reactor vessel and reactor coolant system (RCS) to prevent core damage that is independent of the M-MIS that will monitor and control RCS pressure for most conditions.

EPRI requires a separate safety-related M-MIS independent of the RCS M-MIS and RCS leak detection M-MIS to maintain an adequate inventory of reactor coolant in the reactor and RCS.

Several diverse and independent systems will be available to remove decay heat. EPRI requires that the independence of the systems be maintained in the M-MIS portion by appropriate segmentation and separation. However, Section 8.2.1.4 of Chapter 10 does not address diversity of the M-MIS equipment. The staff's conclusions on the need for diversity are given in Section 6.1.6 of this chapter.

The M-MIS will provide the monitoring and control necessary for containment isolation, from detection of the need through initiation, completion, and confirmation of the completion and maintenance of the isolation.

The M-MIS will provide the control and monitoring necessary to maintain the integrity of the boundary of the containment. This function includes containment cooling and pressure control as well as the monitoring and control of related areas such as suppression-pool level and cooling to ensure availability of the mitigation function.

EPRI states that monitoring to determine the potential for radioactivity release and the control necessary to limit the release will be provided.

8.2.2 Boundaries and Interfaces

Section 8.2.2 of Chapter 10 states that the physical boundaries that make up the safety systems are defined in Chapter 5 of the Evolutionary Requirements Document and that the M-MIS boundaries will be consistent with the physical boundaries of the plant systems.

8.2.3 Common Control and Monitoring Strategies for Reactor Protection and Safety Systems

Section 8.2.3 of Chapter 10 states that the M-MIS designer will use a consistent design strategy. The control strategies will also be consistent with those for the non-safety-related M-MIS.

The protection and safety system M-MIS will provide for normal automatic startup or actuation. Capability for manual initiation will be provided. EPRI indicates that automatic initiation may not be required, if justified. It also indicates that unnecessary automatic initiation of certain systems would increase plant complexity and the potential for inadvertent actuation of the system.

Section 8.2.3.2 of the Chapter 10 originally stated that the M-MIS will be designed for automatic action for the first 20 minutes after actuation. However, EPRI revised Section 8.2.3.2 to state that the M-MIS will be designed for automatic action for the first 30 minutes. In the DSER for Chapter 10, the staff identified the time period for automatic actuation as a confirmatory issue. Therefore, this DSER confirmatory issue is closed.

Normal shutdown functions will be accomplished manually. Testing during operation will be manually initiated but will normally be accomplished automatically during station operation.

8.3 Reactor Protection System

8.3.1 System Definition

Section 8.3.1 of Chapter 10 of the Evolutionary Requirements Document indicates that the RPS will include the sensors through the final actuation breakers or relays. This is consistent with the RPS definition at existing plants. Also included is the test and diagnostic equipment needed to maintain the RPS in a state of readiness, confirm its operational status, or determine the type and location of faults. The staff agrees with the inclusion of the test and diagnostic equipment and software as part of the RPS.

The RPS will monitor plant parameters and determine when reactor shutdown is needed. The systems with which the RPS will interface are

- the neutron monitoring system
- the reactor and reactor coolant system
- the main steam and main turbine-generator systems
- the control rod drive system
- the electric power distribution system
- the heating, ventilating, and air conditioning system

8.3.2 Performance

Section 8.3.2 of Chapter 10 states that the designer will provide the minimum set of variables for the RPS and should minimize anticipatory or diverse trips. EPRI's intent is that the designer justify the trips selected. The staff agrees with the avoidance of unnecessary trips, but each trip function must be evaluated separately. In its request for additional information dated April 10, 1990, the staff asked EPRI to provide additional information because this section appeared to present a potential reduction in safety margins. By letter dated July 23, 1990, EPRI responded that the requirement was not intended to disregard common-mode failures or regulations. In the response, EPRI described the tradeoff in optimum trip signal selection as a qualitative balance that the designer must achieve, but that may not be practical to quantify in the Evolutionary Requirements Document. EPRI committed to clarify the requirement. The staff identified tradeoff in trip signal selection as a confirmatory issue in the DSER for Chapter 10. In Revision 1, EPRI revised Section 8.3.2 to describe the backup RPS actions that will be used to address the potential for common-mode failures and the regulations pertaining to anticipated transients without scram (ATWS). The revision is acceptable because it does not conflict with current regulatory guidance; therefore, this DSER confirmatory issue is closed.

EPRI requires that once the RPS logic initiates a reactor shutdown, the process will continue until completion. After reactor shutdown has been completed, manual action is required to reset the RPS logic and permit rod withdrawal.

The RPS will be single failure proof. A second failure will not prevent protective action but may result in inadvertent actuation. The second-failure criterion proposed by EPRI does not apply to the reactor trip breakers or testing configurations. In the DSER for Chapter 10, the staff concluded that this requirement was acceptable, but recommended that EPRI clarify whether the actuation logic will be continuously self-tested during normal operation. It identified continuous self-testing of actuation logic as an open issue.

In its response dated January 28, 1992, EPRI stated that Section 8.3.2.3 of Chapter 10 requires that the RPS provide for automatic self-testing of as much of the system as is practicable. EPRI also stated that during normal operation, all or essentially all of the actuation logic is expected to be self-tested automatically. This is acceptable because it does not conflict with current regulatory guidance. Therefore, this DSER open issue is closed.

However, the staff will evaluate this item during its review of an individual application for FDA/DC.

EPRI states that the RPS will be designed so that the coincidence logic will only be from different channels but will use the same variable. Coincidence of different variables will not be used. In its response dated July 23, 1990, to a staff request for additional information dated April 10, 1990, EPRI provided an example of the intent of this requirement. The example showed that there were more combinations of two variable inputs that would result in a trip output with different variable logic than with the same variable logic. EPRI stated that the primary consideration in the example was that a single input from two different variables (pressure and temperature) was a less valid indication of a true trip condition than two inputs from the same variable.

Manual initiation of the protection actions will be independent of the automatic initiation. This does not include the reactor trip breakers.

Section 8.3.2.1 of Chapter 10 states that the RPS for BWRs will provide the control signals for the electric control rod drive motors if the primary scram is not effective. This function will be performed by a portion of the BWR RPS separate from the portion of the RPS that controls the primary scram initiation. The backup system that will provide the electric motor initiation will not be single failure proof. This meets the requirements of the ATWS rule (10 CFR 50.62) and is acceptable.

Section 8.3.2.2 of Chapter 10 requires that the PWR designer either provide a diverse backup reactor trip system or demonstrate that the design of the plant has enough features or margin so that the backup system is not warranted. In its request for additional information dated April 10, 1990, the staff questioned the use of a design margin analysis in lieu of the backup scram system and also asked EPRI to address the use of diverse sensors. In a letter dated July 23, 1990, EPRI proposed a revision to this section requiring that the designer retain the option of complying with the ATWS rule or demonstrating that the plant can withstand an ATWS event. In the DSER for Chapter 10, the staff identified compliance with the ATWS rule as a confirmatory issue. The staff has verified that the section has been revised; therefore, this DSER confirmatory issue is closed.

In its letter dated July 23, 1990, EPRI also stated that the rule does not require diverse sensors and the Evolutionary Requirements Document does not require them unless the designer determines they are necessary. The staff concludes that this is acceptable.

The RPS will provide for automatic self-testing.

8.3.3 Configuration

Section 8.3.3 of Chapter 10, as modified by EPRI's January 24, 1992, letter, requires that the RPS be located in a vital area, and, where practicable, the segments of the system are to be located in physically separate locations to make it more difficult for unauthorized personnel to disable the system without detection. Section 5.2.4.2 of Chapter 9 also provides requirements that apply to access to the RPS segments. The staff notes that the RPS would be protected further if it were in one or more vital area within the plant protected area.

RPS initiation, completion, and other status information will be displayed to the main control room (MCR) operators. Safeguards against inadvertent or unauthorized changes in RPS setpoints, including features to ensure proper approval and recording of changes, will be provided.

8.3.4 Equipment Requirements

Section 8.3.4 of Chapter 10 states that highly reliable components will be used in the RPS.

The designer will identify problems associated with the existing reactor trip breakers and will establish functional and design requirements, specifications, and testing requirements to address the problems identified. EPRI specifies that the designer will select a reactor trip device that will not degrade over the design life (60 years) of the plant. EPRI's rationale indicates that the primary concern with regard to these requirements is the metal-clad air circuit breakers. These circuit breakers have experienced a number of problems, including deficiencies in undervoltage trip attachments, lubricants, and manufacturing tolerances.

In the DSER for Chapter 10, the staff identified tamper-proof reactor trip breakers as a confirmatory issue because in its letter of October 12, 1990, EPRI had committed to modify the Evolutionary Requirements Document to add a requirement that the M-MIS designer consider features in the reactor trip breakers or their enclosures that would make it difficult to tamper with the breaker in a manner that would prevent its operation, provided these features had been proven in service and would not prevent the breaker from tripping. The staff has verified that Section 8.3.4.3 of Chapter 10 contains this requirement. The staff concludes that this change satisfies EPRI's commitment; therefore, this confirmatory issue is closed.

A manual reactor trip control will be provided in the MCR that is readily accessible to the operators; capable of operation by a single operator, but protected against inadvertent operation; and easily operated.

8.4 <u>BWR Reactor Core Isolation Cooling System M-MIS</u>

Section 8.4 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the BWR reactor core isolation cooling (RCIC) system will provide the monitoring and control of reactor water inventory if normal feedwater is not available. This part of the M-MIS will not require ac power. The RCIC system will be automatically initiated and then manually controlled.

8.5 <u>BWR High-Pressure Injection System M-MIS</u>

Section 8.5 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the BWR high-pressure injection (HPI) system will provide the monitoring and control needed to maintain reactor coolant inventory if normal feedwater is not available and the RCIC system has not maintained inventory.

The HPI system will be automatically initiated and controlled. Although not specifically stated in the Evolutionary Requirements Document, NRC requirements include requirements for manual initiation and control capability. Since the Evolutionary Requirements Document does not take exception to these requirements, Section 8.5.2 is acceptable.

8.6 BWR Decay Heat Removal System

Section 8.6 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the BWR decay heat removal (DHR) system will provide the monitoring and control needed to

- remove decay and sensible heat from the reactor after shutdown and after the reactor pressure is reduced to 135 psig (saturated conditions)
- maintain reactor coolant inventory if other inventory maintenance systems are not available
- remove heat from the suppression pool
- remove heat from the containment
- remove heat from the fuel pool

The inventory maintenance function of the DHR system will be automatically initiated. The other functions, such as the fuel pool supplemental cooling, will be manually initiated and controlled.

8.7 BWR Standby Liquid Control System M-MIS

Section 8.7 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the standby liquid control (SLC) system will provide the monitoring and control for the poison injection system. The M-MIS for the SLC system will be coordinated with the M-MIS for other plant systems only to the minimal amount necessary to determine when it is needed and to isolate the reactor water cleanup system.

In Revision 4 to Chapter 10 Section 8.7.2, EPRI requires that the SLC system be automatically initiated. The staff's evaluation of the SLC system is provided in Section 2.5.4 of Appendix B to Chapter 1 and Sections 4.2 and 4.3 of Chapter 5 of this report.

8.8 PWR Residual Heat Removal System M-MIS

Section 8.8 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR residual heat removal (RHR) system will provide the monitoring and control needed to remove decay heat when the RCS is at reduced pressure.

The RHR system will be manually initiated. Normal cold shutdown operation will be automated to the extent necessary to eliminate continuous operator attention.

8.9 PWR Emergency Feedwater System M-MIS

Section 8.9 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR emergency feedwater (EFW) system will provide the monitoring and control needed to remove decay heat through the steam generators when the main and startup feedwater systems are not available.

The M-MIS for the EFW system will provide for automatic initiation but will include monitoring to allow the operators to manually initiate the system before the automatic initiation setpoints are reached.

8.10 PWR Safety Injection System M-MIS

Section 8.10 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR safety injection (SI) system will provide the monitoring and control needed to maintain the inventory in the RCS, control excess reactivity of the reactor core by injecting water with a neutron absorber, and remove reactor decay heat by feed-and-bleed operations.

The SI system will be automatically initiated. Manual initiation and control will also be provided.

8.11 PWR Safety Depressurization and Vent System M-MIS

Section 8.11 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR safety depressurization and vent (SDV) system will provide the monitoring and control needed to maintain the RCS pressure when normal systems are unavailable, vent noncondensible gases from the RCS, and bleed reactor coolant from the RCS during feed-and-bleed operations.

The SDV system will be manually actuated. The Evolutionary Requirements Document emphasizes avoiding inadvertent actuation of this system, since the actuation would, in effect, result in a loss-of-coolant accident (LOCA).

8.12 Containment Isolation M-MIS

Section 8.12 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the containment isolation system will provide the monitoring and control necessary to isolate the containment in order to minimize the release of radioactivity to the environment.

Containment isolation will be automatically initiated and accomplished. A comprehensive operator display and appropriate controls will be provided.

8.13 Containment System M-MIS

Section 8.13 of Chapter 10 of the Evolutionary Requirements Document contains requirements for the monitoring and control needed to keep radioactive material inside the containment. The monitoring of conditions inside the containment will not require direct operator action, but information displaying the status of the containment will be provided.

8.14 PWR Containment Spray System M-MIS

Section 8.14 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the PWR containment spray system will provide the monitoring and control necessary to

- remove heat from the containment atmosphere following a design-basis accident
- reduce the concentration of fission products in the containment atmosphere following design-basis accidents
- remove reactor decay heat from the in-containment refueling water storage tank during post-LOCA operation

Spray initiation will be automatic with manual actuation as a backup. The designer will incorporate features to prevent inadvertent actuation or manual initiation. Pump realignments will be manually initiated.

8.15 Combustible Gas Control System M-MIS

Section 8.15 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the combustible gas control system will provide the monitoring and control necessary to ensure containment integrity even if combustible gas has been released during an accident. This system will be manually actuated.

8.16 Fission Product Leakage Control System M-MIS

Section 8.16 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the fission product leakage control (FPLC) system will provide the monitoring and control needed to limit potentially radioactive leakage to the environment. Features for automatic monitoring and automatic interlocks will be provided for this system.

8.17 Conclusion

The staff concludes that item the requirements in Section 8 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are, therefore, acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

9 POWER GENERATION AND MAIN TURBINE-GENERATOR SYSTEMS M-MIS REQUIREMENTS

9.1 Purpose and Scope

Section 9.1 of Chapter 10 of the Evolutionary Requirements Document states that Section 9 provides the requirements for the M-MIS that will monitor and control the power generation and main turbine-generator systems.

EPRI specifies that the M-MIS for the systems addressed in Section 9 will be coordinated and integrated with the M-MIS for other plant systems.

9.2 General Requirements for Power Generation and Main Turbine-Generator Systems Group M-MIS

Section 9.2 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for these systems will provide the monitoring and control necessary for the systems to transport steam to the main turbine and to control steam pressure and moisture content, feed and condensate system operations, and the auxiliary steam system.

Section 9.2.2 of Chapter 10 states that the physical boundaries that will make up the power generation and main turbine-generator systems are defined in Chapters 2 and 13 of the Evolutionary Requirements Document. EPRI states that the boundaries of the M-MIS will be consistent with the physical boundaries of the plant systems.

Section 9.2.3 of Chapter 10 states that these systems will use the common control strategies that the other M-MIS systems will use. The startup functions will be performed manually by the operator. The designer will determine the need for automatic operation during startup or shutdown. Normal operations above a low power level will be automatic. The M-MIS will automatically reconfigure or shut down the system.

The systems will be returned to normal operation after reconfiguration or will be shut down by manual action unless the designer establishes functions that need to be automated. Any automatic return to operation will be annunciated to the operators. On-line testing for these systems will be initiated by the operators, but the actual testing will be automated.

9.3 Main and Extraction Steam System M-MIS

Section 9.3 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the main and extraction steam system will provide the monitoring and control needed to transport the steam to the main turbine and to maintain steam quality.

The designer will provide for smooth transfers between automatic and manual control. The M-MIS will provide for maneuvering and load following as needed without short-term operator action. The actions of this system will be compatible with those of the reactor and safety systems. The control strategy will be compatible with on-line testing.

9.4 Main Turbine System M-MIS

Section 9.4 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the main turbine system will provide the monitoring and control for the main functions of the turbine.

9.5 Main Generator System M-MIS

Section 9.5 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the main generator system will provide the monitoring and control for the main generator.

9.6 Feedwater and Condensate System M-MIS

Section 9.6 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the feedwater and condensate system will provide the monitoring and control needed to transport high-quality feedwater from the condenser hotwell to valves that control the introduction of feedwater into the BWR reactor vessel or a PWR steam generator.

Operation at low power levels will be automatic. Features will be provided that will ensure that transfer between manual and automatic control is smooth. The feedwater and condensate system will be automatically adjusted during normal power changes without short-term operator action.

9.7 Chemical Addition System M-MIS

Section 9.7 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the chemical addition system will provide the monitoring and control needed to maintain the condensate, feedwater, and off-gas chemistry within required limits.

The designer will determine the operations that will be controlled from the main control room instead of locally. Automatic operation of the chemical addition system will not cause a shutdown of other plant systems.

9.8 Condensate Makeup and Purification System M-MIS

Section 9.8 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the condensate makeup and purification system will provide the monitoring and control needed for makeup water supply and chemistry.

Normal operation will be automatic. Automatic actions of this system, including component failures, will not cause a shutdown of other plant systems unless the shutdown is necessary to prevent hazards to personnel or damage to other equipment.

9.9 Auxiliary Steam System M-MIS

Section 9.9 of Chapter 10 of the Evolutionary Requirements Document states that the M-MIS for the auxiliary steam system will provide the monitoring and control necessary to ensure an adequate supply of auxiliary (low-pressure) steam is available to the plant systems that will use auxiliary steam to perform their functions.

EPRI expects that most or all of these functions will be performed outside the main control room (MCR). The designer will stipulate any functions that are essential enough to be included in the MCR. Automatic actions of this system, including component failures, will not cause a shutdown of other plant systems unless the shutdown is necessary to prevent hazards to personnel or damage to other equipment.

9.10 Conclusion

The staff concludes that the requirements in Section 9 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are, therefore, acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

10 AUXILIARY AND PLANT SUPPORT SERVICES SYSTEMS M-MIS REQUIREMENTS

10.1 Purpose and Scope

Section 10.1 of Chapter 10 of the Evolutionary Requirements Document states that Section 10 provides the general requirements for the M-MIS that will monitor and control the auxiliary and plant support services systems. The auxiliary systems covered by this section include the plant cooling water system; the compressed air and gas systems; the heating, ventilating, and air conditioning system; and the electric power system. The plant support services systems include the fuel handling systems, the fire protection system, the environmental monitoring system, the site security system, and the radioactive waste processing systems.

10.2 General Requirements for Auxiliary and Plant Support Services Systems Groups M-MIS

10.2.1 Functions

The M-MIS will provide the monitoring and control for the systems listed in Section 10.1 of Chapter 10 of the Evolutionary Requirement Document. Because the function of each M-MIS for these systems is self-explanatory, the staff has not addressed them individually. However, the following discussion addresses the staff's concerns regarding certain requirements proposed by EPRI for the M-MIS for specific systems.

In the DSER for Chapter 10, the staff identified of security functions of the M-MIS as an open issue because the list of site security functions that the M-MIS designer was required to consider in Section 10.2.1.8 of Chapter 10 omitted the critical function of security response to alarms, as required by 10 CFR 73.55(h). EPRI has revised Section 10.2.1.8 to clarify that the M-MIS for the plant security system must meet the security system requirements of Section 5 of Chapter 9 of the Evolutionary Requirements Document, and the recordkeeping requirements of 10 CFR 73.70(b), (d), and (f), as well as the applicable general requirements for an M-MIS in Chapter 10. Because Section 5 of Chapter 9 includes the communication requirements of 10 CFR 73.55(h), the staff concludes that this change adequately addresses its concern; therefore, this open issue is closed.

In the DSER for Chapter 10, the staff identified the lack of specific criteria on the quality, placement, and calibration frequency of the area monitors described in the Evolutionary Requirements Document as an open issue. However, in Revision 2 of Appendix B to Chapter 1, EPRI committed to meet the SRP guidance on an acceptable area radiation monitoring system. Since EPRI has committed to meet SRP Sections 12.3 and 12.4 "Radiation Protection Design Features" and since it is outside the scope of the Evolutionary Requirement Document to provide detailed information on the area radiation monitoring equipment to be used at the ALWR, the staff concludes that this open issue is closed. The staff will review individual applications for FDA/DC to ensure that the detailed information on the area radiation monitoring system that is called for in SRP Sections 12.3 and 12.4 is provided.

Item II.F.1-3 of NUREG-0737 states that licensees must have the capability to detect and measure the radiation levels within the containment during and following an accident. Since Revision 1 of the Evolutionary Requirements Document did not reference compliance with Item II.F.1-3, the staff identified this as an open issue in the DSER for Chapter 10. However, in Revision 2 of Appendix B to Chapter 1, EPRI committed to comply with 10 CFR 50.34(f)(2)(xvii), which addresses Item II.F.1-3 of NUREG-0737 on accident monitoring instrumentation. On the basis of this commitment the open issue concerning compliance with Item II.F.1-3 of NUREG-0737 is closed. The staff will review individual applications for FDA/DC to ensure that description of the specific design features necessary to comply with Item II.F.1-3 of NUREG-0737 are described.

SRP Sections 12.3 and 12.4 describe the criteria for an acceptable airborne radioactivity monitoring system. These criteria address location, placement, calibration frequency, and alarm and readout for airborne radioactivity monitors. In addition, these SRP sections include emergency power requirements and setpoint levels for these monitors. Since the Evolutionary Requirements Document did not initially address criteria for an airborne radioactivity monitoring program, the staff identified this as an open issue in the DSER for Chapter 10. However, in Revision 2 to Appendix B, EPRI committed to require that the guidelines of SRP Sections 12.3 and 12.4 be met. On the basis of this commitment, this open issue is closed. Since it is outside the scope of the Evolutionary Requirements Document to provide detailed information on the airborne radioactivity monitoring system, the staff will review individual applications for FDA/DC to ensure that this information is provided.

10.2.2 Boundaries and Interfaces

Section 10.2.2 of Chapter 10 states that the physical boundaries that make up the auxiliary and plant support services systems are defined in Chapters 7, 8, 9, 11, and 12 of the Evolutionary Requirements Document. The boundaries of the M-MIS for these systems will be consistent with the physical boundaries of the plant systems.

10.2.3 Control and Monitoring Strategies for Auxiliary and Support Systems

Section 10.2.3 of Chapter 10 states that a consistent control strategy will be used. These systems will primarily be operated from outside the main control room. Monitoring and control will be provided for normal startup and shutdown. Some tasks may be automated. Normal operations of these systems will be performed automatically.

The M-MIS will provide automatic reconfiguration when needed for investment protection or safety. Normal on-line testing will be initiated by the operators, but the testing will be automated.

<u>Security Concerns</u>

In the DSER for Chapter 10, the staff identified manning of the M-MIS that controls security functions as an open issue. In its letter of January 28, 1992, EPRI revised Section 10.2.3.2 of Chapter 10 by requiring the following:

> In the case of systems which are continuously manned, such as the security system, many of the operator actions inherently cannot be automatic; however, the operators of such systems (security officers, for example) should not be burdened with routine tasks needed to keep the system configured such that the operators or plant staff can perform their normal tasks.

This change adequately addresses the staff's concern; therefore, this open issue is closed.

In the DSER for Chapter 10, the staff identified automatic reconfiguration of the M-MIS that controls security functions as an open issue because the staff was concerned that Section 10.2.3.3 of Chapter 10 specifies automatic reconfiguration of plant support services group of systems, including site security systems. Changes in security status (e.g., from "secure" to "access" and vice versa) are functions that must remain under the control of the security console operator. In its letter dated January 28, 1992, EPRI argued that Section 10.2.3.3 neither requires nor allows automatic changes in security status. It pointed out that automatic reconfiguration is only allowed by Section 10.2.3.3 when necessary. Other changes in configuration, will be performed manually. As the staff and EPRI are in agreement on the need for manual control of security system reconfiguration, this issue is closed. The staff will review individual applications for FDA/DC to verify that the security system does not automatically go into access status whenever the reactor is automatically shut down.

In the DSER for Chapter 10, the staff identified automatic self-testing feature of the M-MIS that controls security functions as an open issue because it was concerned that Section 10.2.3.4 of Chapter 10 specifies on-line testing be provided normally only at the direction of the plant staff. In its letter dated January 28, 1992, EPRI argued that the use in Section 10.2.3.4 of the term "normally" makes this provision conditional, rather than absolute, and that on-line self-testing and automatic testing of the security system were not only not precluded by this requirement, but would be consistent with minimizing the burden on the operators. EPRI further noted that Section 5.3.2 of Chapter 9 specifically requires security system design to include self-test logic circuitry. As the staff and EPRI are in agreement on the need for automatic testing of some security functions, this open issue is closed.

10.2.4 Integration and Coordination

Section 10.2.4 of Chapter 10 states that the M-MIS for the systems addressed in Section 10 will be integrated and coordinated with the M-MIS for other systems.

10.2.5 Independence and Redundancy Requirements

Section 10.2.5 of Chapter 10 states that the M-MIS will be independent and redundant as defined for the particular system. Failures in the M-MIS for the systems addressed in Section 10 will not cause plant unavailability or challenge the reactor protection or engineered safety feature actuation systems.

Specific requirements for independence of the security M-MIS are contained in 10 CFR 73.55(e)(1), which requires that the security central alarm station not contain any other activities that could interfere with its security functions. Section 5.2.13.1 of Chapter 9 of the Evolutionary Requirements Document states that all security central processing units will be dedicated to security functions only. However, the requirements in Chapter 9 for the security system do not require independent data transmission between protected area perimeter intrusion detection sensors and the central and secondary alarm stations. As discussed by the staff in Sections 5.2.1 and 5.2.5 of this chapter, independent data transmission of these alarms and associated closed-circuit television signals may be necessary to ensure a capability that meets the alarm assessment requirements of 10 CFR 73.55(h)(4)(i) and (ii). Although Section 10.2.5 of Chapter 10 does not explicitly cover this potential need for independence, it does not prohibit this independence and, thus, does not conflict with NRC requirements.

10.2.6 Fire Protection and Security

Section 10.2.6 of Chapter 10 states that the M-MIS will enhance the plant capability for fire protection and security by providing alternative controls and monitoring so that fires and actuation of fire suppression will not require plant shutdown because M-MIS equipment is not available.

10.3 <u>Conclusion</u>

The staff concludes that the requirements in Section 10 of Chapter 10 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are, therefore, acceptable. However, by themselves, they do not provide sufficient information to make a determination that a specific design application will be acceptable. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the guidance in the Standard Review Plan or provide justification for alternative means of implementing the associated regulatory requirements.

11 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 10 of the Evolutionary Requirements Document for the design of man-machine interface systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the plant-specific design, operation, and arrangement of the man-machine interface systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the Standard Review Plan (NUREG-0800), or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 10 specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose man-machine interface systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS OF TERMS AND ACRONYMS

Appendix A of Chapter 10 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
GENERIC SAFETY AND LICENSING ISSUES

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address the resolution of generic safety issues in Appendix B to each chapter. In the DSER for Chapter 10 of the Evolutionary Requirements Document, the staff evaluated EPRI's requirements to address the resolution of the following generic safety issues:

- 2, "Failure of Protective Devices on Essential Equipment"
- 75, "Generic Implications of ATWS Event at Salem Nuclear Power Plant"
- 76, "Instrumentation and Control Power Interaction"
- 101, "Break Plus Single Failure in BWR Water Level Instrumentation"
- 110, "Equipment Protective Devices on Engineered Safety Features"
- 115, "Enhancements of the Reliability of Westinghouse Solid State Protection System"
- 122.2, "Initiating Feed-and-Bleed"
- 125.I.3, "Long-Term Generic Actions as a Result of the Davis-Besse Event of June 9, 1985 - SPDS Availability"
- 125.I.4, "Long-Term Generic Actions as a Result of the Davis-Besse Event of June 9, 1985 - Plant-Specific Simulator"
- 125.I.5, "Long-Term Generic Actions as a Result of the Davis-Besse Event of June 9, 1985 - Safety Systems Listed in All Conditions Required by Design Basis Analysis"
- 125.I.6, "Long-Term Generic Actions as a Result of the Davis-Besse Event of June 9, 1985 - Valve Torque Limit and Bypass Switch Settings"
- 125.II.13, "Long-Term Generic Actions as a Result of the Davis-Besse Event of June 9, 1985 - Operator Job Aids
- 127, "Testing and Maintenance of Manual Valves in Safety-Related Systems"
- A-47, "Safety Implications of Control Systems"
- B-17, "Criterion for Safety-Related Operator Actions"
- HF 4.4, "Guidelines for Upgrading Other Procedures"
- HF 5.1, "Local Control Stations"
- HF 5.2, "Review Criteria for Human Factors Aspects of Advanced Controls and Instruments"

In Revision 1 of the Evolutionary Requirements Document, submitted by letter dated September 7, 1990, EPRI relocated its requirements to address generic safety issues that were unresolved as of January 1, 1990, to Appendix B to Chapter 1. As a result, a number of generic safety issues that were addressed in the original Evolutionary Requirements Document are no longer addressed. The staff's evaluation of EPRI's requirements to address generic safe*·· issues is given in Appendix B to Chapter 1 of this report. The staff has also documented its clo ure of open and confirmatory issues associated with generic safety issues no longer addressed by EPRI in Appendix B to Chapter 1 of this report. Therefore, the DSER open and confirmatory issues associated with Unresolved Safety Issues B-17 and with Generic Safety Issues 2, 75, 76, 101, 110, and HF 4.4 are closed.

APPENDIX C
ADVANCED CONTROL ROOM DESIGN

Appendix C to Chapter 10 of the original Evolutionary Requirements Document contained requirements for a computer-based control room with an integrated M-MIS featuring electronic displays for monitoring and with workstation controls not dedicated to a single function. A single, large minus board with algorithm capabilities was intended to provide operators with more informative and effective displays, compared to older technologies. By letter dated April 10, 1990, the staff identified a number of concerns regarding EPRI's design requirements for an advanced control room, including interpretation of the single-failure criterion, EPRI's segmentation policy, and operator performance. In a letter dated July 23, 1990, EPRI committed to clarify its requirements in other sections of Chapter 10, concluded that Appendix C to Chapter 10 was not needed, and committed to delete this appendix. In the DSER for Chapter 10, the staff discussed its concerns pertaining to Appendix C in other sections of the DSER and identified the deletion of Appendix C from Chapter 10 as a confirmatory issue.

EPRI has deleted Appendix C from Chapter 10 of the Evolutionary Requirements Document. The staff has verified that the issues formerly presented in Appendix C are discussed in other sections of Chapter 10. Therefore, this confirmatory issue is closed.

APPENDIX D
HUMAN FACTORS ASSESSMENT OF EVOLUTIONARY REQUIREMENTS DOCUMENT

1 INTRODUCTION

This appendix documents the staff's review of the human factors aspects of the Evolutionary Requirements Document. The staff's review included the original version of Chapter 10, submitted on October 26, 1989; EPRI's letters dated December 6, 1990, January 28, 1992, and February 3, 1992; portions of other chapters that contain applicable human factors considerations; and Revisions 1 through 4 of Chapter 10.

Chapter 10 of the Evolutionary Requirements Document contains the majority of human factors requirements proposed by EPRI. Chapters 1, 6, 7, 8, 9, and 11 also contain human factors considerations and refer to Chapter 10 for additional details. Hence, the evaluation of Chapter 10 contained herein serves as the staff's human factors review of the entire Evolutionary Requirements Document.

The staff's review was based on the regulatory requirements in 10 CFR 50.34(g) and 10 CFR 52.47 and the guidance in Sections 13 and 18 of NUREG-0800, "Standard Review Plan [SRP] for the Review of Safety Analysis Reports for Nuclear Power Plants," and NUREG-0700, "Guidelines for Control Room Design Reviews."

2 STAFF REVIEW OF HUMAN FACTORS IN ADVANCED PLANTS

Current regulatory guidance on human factors is contained in Sections 13 and 18 of the SRP. Section 18, "Human Factors Engineering," provides guidance fo the review of the design of existing control rooms, remote shutdown control stations, and safety parameter display systems to ensure that the interfaces between the systems, structures, and components and the plant personnel that operate them have been designed and built to conform with accepted human factors practices (i.e., practices accepted by human factors professionals). SRP Section 13, "Conduct of Operations," contains review guidance for issues related to the qualification of operators; training of plant staff; and the development and implementation of normal, abnormal, and emergency operating procedures. In addition, NUREG-0700, which is referenced in SRP Section 18, contains guidance on the use of systems and operations design analysis techniques for new control room designs.

The staff's review of the Evolutionary Requirements Document went beyond the current human factors guidance in SRP Sections 13 and 18 because the present criteria were developed to evaluate limited backfit modifications and improvements to existing nuclear power plants. The human factors considerations addressed in the Evolutionary Requirements Document are intended for a new plant design that will use technology not currently found in operating U.S. commercial nuclear power plants. Accordingly, the staff has developed new positions based on accepted human factors principles and practices for a new plant design using new technology. These positions were applied in the staff's review.

The staff has taken the position that an integrated and systematic approach to human factors should be used from the start of an advanced reactor design to aid in achieving the goal of increased safety and reliability by reducing the probability of operator error and risk to public health and safety. Advanced reactor man-machine interface systems should be designed only after complete plant and systems analyses have been performed. Systems analysis should include function analysis, function allocation, and verification and validation of function allocation. The functions defined by the function analysis will provide the basis for subsequent task analyses to establish the information and control requirements needed to develop control station design, procedures, and training. The goal of this approach to design is to ensure that the control stations, procedures, and training and staffing requirements fully support the operators in accomplishing required functions in a safe and reliable manner. Only through a systematic and properly organized approach can an advanced reactor designer demonstrate that human performance has been appropriately considered in the design.

The advanced reactor control and display designs proposed by the ALWR vendors are significantly different from current nuclear power plant control stations. The use of computerized workstations, digital technology such as electronic displays and "soft" controls, and increases in automation make it imperative that allocations of functions to humans and systems are carefully addressed and that systems will be optimized to take full advantage of the strengths of humans and advanced, automated systems. Item (II)(B) the SRP Section 18.1 states that new reactor control stations should use advanced display and control technologies and should provide the means for data gathering, formatting, and processing that support operator functions and tasks and aid reliability under all plant operational modes and conditions. Vendors must demonstrate that these advanced technologies are technically feasible within the state-of-the-art and that they incorporate accepted human factors principles.

Sections 1.4.1, 2, and B1 of NUREG-0700 advocate that the designer develop a human factors program plan as the first step of the control room design process. Similarly, the staff has taken the position that advanced reactor designers should include a human factors program as part of the development of the plant design. The program should cover all aspects of human factors that contribute to plant safety and reliability and should address at a minimum (1) human-system interfaces for personnel interaction and interventions at the function, system, or component level; (2) the staffing and qualification requirements for personnel; (3) the development of procedures and training for normal, abnormal, and emergency modes of plant operation; (4) maintainability of plant equipment; and (5) training and procedures for maintenance tasks. Consistent with Section 2.1 of Appendix A to Section 18 of the SRP and Sections 2.3 and B3 of NUREG-0700, it is also essential that the human factors program include full participation of qualified human factors specialists during all phases of the design process to minimize post-design problems and changes. Also, because advanced systems are being proposed for ALWRs, the advanced reactor designer's human factors program plan should include the necessary human factors tests and evaluations to verify that the anticipated improvements in human performance have been achieved. This approach conforms to the guidance in Sections 3.7, 3.8, and B4.3.2.6 of NUREG-0700.

The staff has also taken the position on human factors and advanced reactor designs that the ALWR designer's human factors program should include the consideration of the need for a control room prototype. Similar guidance is contained in Sections 3.8 and B4.4 of NUREG-0700. The need would be based on an evolutionary-design-specific evaluation of the amount of advanced technology proposed in the design and the potential for new operator interface requirements. A prototype would be used as necessary to conduct human factors tests and evaluations for ensuring that the ALWR control room designs are consistent with the plant operating philosophy, and provide the necessary assurance that an appropriate reduction in the probability of operator error is achieved. Because the evolutionary ALWR control rooms proposed to date will have computer-driven workstations unlike any in current U.S. nuclear power plants, prototypes may be needed to conduct the experimentation and testing necessary to verify the adequacy of the design.

3 EVALUATION

The staff's human factors evaluation of the Evolutionary Requirements Document follows. As discussed in Sections 1 and 2 of this appendix, the staff's positions and evaluation are based on the regulatory requirements in 10 CFR 50.34(g) and 10 CFR 52.47, the guidance in SRP Sections 13 and 18 and in NUREG-0700, and accepted human factors principles and practices. Each section co tains the staff's position, citations from applicable parts of the Evolutionary Requirements Document, and the staff's evaluation of the adequacy of e cited requirements of the Evolutionary Requirements Document when compared to the staff's position. Where the Evolutionary Requirements Document does not contain sufficient information to satisfy the applicable staff positions, the staff concludes that the applicant for final design approval/design certification (FDA/DC) will be required to provide this information.

3.1 Organizational Structure of the Human Factors Function

On the basis of the guidance in Section 2.1 of Section 18.1 of the SRP, Sections ..3 and B3 of NUREG-0700, and accepted human factors principles and practices, the organizational structure, personnel, and methods and criteria to be used to integrate human fact into the design process should be identified and described. As a um, the following elements should be included as part of the human fac organizational structure:

- reporting responsibilities and authority of the human factors staff
- the qualifications and number of human factors personnel and job descriptions for each position
- the role of human factors in a multidisciplinary design team

Sections 3..2.2, 3.1.2.3, 3.1.4.1, and 4.1.3.1 of Chapter 10 of the Evolutionary Requirements Document specify that the man-machine interface system (M-MIS) designer will organize, direct, and establish the main control room design team, the independent review team, and the control station review team.

Generally, each of the four sections referenced above specifies the makeup of the team(s) by engineering and design disciplines and specialties, as well as the inclusion of human factors specialist(s) and plant owner staff representatives. The staff concludes that this team makeup is acceptable. However, the Evolutionary Requirements Document does not contain a requirement specifying that computer software and hardware specialists be included on the design and review teams. In its response dated January 24, 1992, to the DSER for Chapter 10, EPRI stated that the Evolutionary Requirements Document had not identified computer software and hardware specialists because it is believed that there is little difference between an instrumentation and control specialist and computer software and hardware specialists. Given the amount of computer software and hardware that will be used in an ALWR and required by Section 6 of Chapter 10 of the Evolutionary Requirements Document, the staff finds that not requiring computer specialists to be on design and review teams could significantly affect the control room design development process. Therefore, the applicant for FDA/DC should ensure that computer software and hardware specialists are on the ALWR design team.

Section 3.1.2.4 of Chapter 10 requires that the M-MIS designer prepare a comprehensive plan for the development and implementation of the M-MIS design that includes elements for scheduling, configuration control, design, development and testing tools, design team interfacing and interactions, and participation of utility representatives. In addition, in its response of December 6, 1990, to an August 30, 1990, request for additional information, EPRI committed to include in Section 3.4, "ALWR Top-Level Design Process Requirements," of Volume 1 of the Requirements Document a requirement that the plant designer have a documented plan for the development and implementation of the ALWR design. The plan should clearly identify the responsibilities and authorities for all aspects of the design process and specifically identify the features that have been incorporated to ensure a systematic consideration of human factors. However, in its response, EPRI did not describe requirements pertaining to (1) the reporting responsibilities and authority of the human factors staff, (2) the qualifications and number of human factors personnel, (3) job descriptions for each position, and (4) the role of human factors in a multidisciplinary design team. In its response dated February 3, 1992, EPRI stated that Section 11.8.5 of Chapter 1 had been revised to include additional EPRI guidance documents for human factors planning and that it considers that these provide the necessary detailed guidance. It is the staff's position that the four elements describing the human factors organizational structure itemized above should be included as part of the Evolutionary Requirements Document and not located in reference documentation. Therefore, the applicant for FDA/DC should demonstrate that the organization and structure of its human factors function meet the above requirements.

3.2 Systems Analysis

Consistent with Sections 3.4 and B4 of NUREG-0700 and accepted human factors principles and practices, the plant designer should conduct a human factors systems analysis, including a function and task analysis, that includes the analysis of plant and system functions, system information flow, and information required for the effective and timely conduct of tasks by operators and maintenance personnel. The systems analysis should include, as a minimum, the following elements:

- identification of interactions required between and among systems to meet plant and personnel performance objectives
- definition of functions and tasks and their allocation to personnel or equipment

- identification of system processes and their allocation to functional, system, or component level of control

- comparison of personnel workload to equipment design constraints and limitations to ensure plant performance objectives are met

- performance of comprehensive task analyses, including the identification of critical tasks and their analysis for equipment design characteristics that exceed human control capabilities or approach limitations

- integration of human factors into the design of hardware and software

The staff's evaluation of the incorporation of these elements in the Evolutionary Requirements Document follows.

3.2.1 Identification of Interactions Between and Among Systems

Section 3.1.3.3 of Chapter 10 requires that the M-MIS design process result in the explicit identification of the functions of the M-MIS needed to control the plant systems and the overall operation of the plant.

Section 7.2.4 of Chapter 10 specifies that the M-MIS designs for the reactor and the reactor coolant systems are to be integrated and coordinated so that the overall plant performance and functional requirements as well as those for the individual systems are met. Plant systems requirements are located in other chapters of the Evolutionary Requirements Document. The specific methods and the logic used to integrate the operation of the various systems are to be selected by the M-MIS designer.

In its request for additional information dated August 30, 1990, the staff questioned the human factors analysis methods, techniques, and documentation requirements proposed by EPRI to implement the human factors policy and top-tier requirements of the Evolutionary Requirements Document. By letter dated December 6, 1990, EPRI stated that it was the responsibility of the plant designer to establish the human factors analysis methods, techniques, and documentation and that the Evolutionary Requirements Document provides the policy and top-tier requirements for human factors and other requirements that affect human factors. EPRI also noted that specific requirements on human factors analysis methods, techniques, and documentation are included in other chapters of the Evolutionary Requirements Document as appropriate, and in some cases, other EPRI guidance documents are referenced to provide further details. In the DSER for Chapter 10 the staff concluded that the Evolutionary Requirements Document did not contain (1) specifications for a systems analysis that would be a part of the human factors program for the ALWR design and (2) specific guidance on the organization of plant information to identify systems and their functional interactions in order to meet plant and personnel performance objectives. Rather, EPRI has left these tasks to be implemented by the plant designer using the top-tier policy and specific human factors requirements distributed throughout the Evolutionary Requirements Document. In its response dated February 3, 1992, to the DSER, EPRI identified specific paragraphs in the Evolutionary Requirements Document that can be interpreted as addressing the staff's concerns. After additional review, the staff concludes that the applicant for FDA/DC will be required to demonstrate that appropriate systems analyses have been performed and that plant information has been properly organized on the basis of these analyses.

3.2.2 Definition of Functions and Tasks and Their Allocation to Personnel or Equipment

Sections 3.1.3.3, 3.1.3.3.1, 3.1.3.3.3, 3.4.3, 3.4.4, and 3.7.7.1 of Chapter 10 specify that the M-MIS design process is to result in (1) the identification of M-MIS operational and maintenance functions and individual tasks necessary to perform the functions, (2) the use of the identified functions and tasks, (3) the selection of automatic or manual control, and (4) the selection of remote or local control. The staff concludes that these requirements are consistent with accepted human factors principles and practices and the guidance in Sections 3.4, B4.1, and B4.2 of NUREG-0700 and are, therefore, acceptable.

3.2.3 Identification of System Processes and Their Allocation to Functional, System, or Component Level of Control

Section 3.1.1 of Chapter 10 specifies that the detailed M-MIS design development process will ensure that the functional requirements of plant systems and other design requirements are met. Also, Section 3.1.1.1 requires that the M-MIS design process be structured to emphasize the functional division of the plant such as reactivity control, reactor coolant pressure control, reactor coolant inventory and chemistry control, and reactor core heat removal for the overall control of the reactor. The staff concludes tha these requirements are consistent with accepted human factors principles and practices and are, therefore, acceptable.

3.2.4 Comparison of Personnel Workload Tasks to Equipment Design Constraints and Limitations

Section 2.1.1 of Chapter 10 requires that the M-MIS design take full advantage of operator capabilities but not challenge operator limitations. Sections 3.1.3.3.3 and 3.1.3.4 specify that the M-MIS design process will provide for the assessment of operator workload and identify operator functions and tasks that result from the consideration of the potential for, and consequences of, failures of plant and M-MIS system components. Section 3.4.1.1 requires that the M-MIS design not require operators to perform tasks that exceed their capabilities. Sections 3.7.7.2 and 3.7.7.3 require that maintenance tasks be evaluated to ensure they are within the expected capability of maintenance technicians and that M-MIS equipment be designed to facilitate maintenance and repair and to minimize confusion and the chance of error during operations. The staff concludes that these requirements are consistent with accepted human factors principles and practices and the guidance in Sections 3.4 and B4.2 of NUREG-0700 and are, therefore, acceptable.

3.2.5 Performance of Comprehensive Task Analyses

Sections 3.1.3.3.2 and 3.7.7.1 of Chapter 10 specify that the design process will provide for the analysis of operations, maintenance functions and tasks, and the validation and evaluation of the allocation of functions to automatic control systems or particular control stations. The staff concludes that these requirements are consistent with accepted human factors principles and practices and the guidance in Sections 3.4 and B4.3 of NUREG-0700 and are, therefore, acceptable.

3.2.6 Integration of Human Factors Into the Design of Hardware and Software

Section 2.2.8 of Chapter 10 establishes a policy for the application of human factors engineering as a formal part of the M-MIS design and design verification process. The ALWR M-MIS design will place particular emphasis on eliminating potential sources of human error, reducing the probability of human error, and providing for the detection of and recovery from human errors, should they occur. Section 4.1.5 specifies that the design process will provide for the defining of the specific detailed design practices as they evolve during design development, and that these practices will be based on published guidance on human factors, such as EPRI NP-3659, "Human Factors Guide for Nuclear Power Plant Control Room Development," and EPRI NP-6209, "Effective Plant Labeling and Coding." In addition, if the designer selects new technology for which published guidance on human factors practice is limited or this is not preferred in accepted human factors guidelines, the designer should perform and document special evaluations and reviews to ensure operator performance is not degraded by the use of the new technology.

Sections 3.1.4.4.1 and 3.1.4.4.2 of Chapter 10 require that the independent review team review the M-MIS functional requirements, system functional designs, and hardware and software specifications to confirm that they are complete, correct, consistent, feasible, and testable. The reviewers are to consider system architecture, interfaces, testability, maintainability, reliability, and the human factors aspects of the M-MIS design. Section 3.1.4.4.3 requires that the reviews performed as outlined in Sections 3.1.4.4.1 and 3.1.4.4.2 include an evaluation of the alternatives and tradeoffs considered by the M-MIS designer and others in establishing the requirements and specifications, and that they address the correction of system and equipment problems experienced with previous designs. The reviews will include all aspects of the design including human factors for operators and maintenance personnel. The staff concludes that these requirements are consistent with accepted human factors principles and practices and the guidance in Section 18.1 of the SRP and Section 6 of NUREG-0700 and are, therefore, acceptable.

3.3 Development and Performance of the Verification of the Design of the Control Room and Local Control Stations

Consistent with the guidance in Section 18.1 of the SRP and Sections 3.7 and B4.4 of NUREG-0700, the staff's position is that the methods and criteria used in the design of the control room and local control stations should conform to accepted human factors principles and practices. For those criteria for which professional acceptance does not exist, appropriate supporting justification is needed.

Section 4 of Chapter 10 of the Evolutionary Requirements Document establishes the requirements for ALWR control stations. Section 4.1 requires that the M-MIS designer establish a process that ensures a consistent design approach for all plant control stations and integrates the identified functions and tasks. Conceptual designs will be based on the initial definition of tasks and reviewed by an interdisciplinary review team that includes personnel with operational experience, human factors specialists, and engineering disciplines. Requirements are also established for the use of mockups and active simulators in the review and evaluation of control stations.

The Evolutionary Requirements Document specifies that EPRI NP-3659 will be used as guidance on human factors detailed design practices for control station development. In addition, requirements are included in Section 4.1 of Chapter 10 specifying that the M-MIS designer will develop the necessary design practices based on the best available information for cases where new technology has been selected and published guidance on human factors is limited. This requirement also specifies that the developed design practice will be verified by experimentation, including live simulation. Experimentation should explicitly be included in the review process with the review team determining the need for further review of design practices by human factors specialists.

Additional requirements in Section 4.1 of Chapter 10 state that widely used and accepted design practices will be given preference by the M-MIS designer. However, if these practices are not preferred in accepted human factors guidelines, the M-MIS designer should perform and document special evaluations and reviews to verify that operator performance is not degraded by their use. The designer should also document deviations from common design practices and the basis for these deviations.

Sections 4.3 through 4.9 of Chapter 10 give the requirements for the following specific control station systems:

- alarms (Section 4.3)
- displays (Section 4.4)
- controls (Section 4.5)
- voice communication systems (Section 4.6)
- arrangement, environment, and equipment (Section 4.7)
- control panels (Section 4.8)
- specific control stations (main control room, local control stations, remote shutdown control stations, emergency response support facilities, technical support center, emergency operations facility, and data-handling and computer facilities) (Section 4.9)

Section 8 of Chapter 9 contains requirements for human factors considerations for heating, ventilating, and air conditioning systems.

Generally, requirements for these systems are similar to, and reference, the requirements in Section 4 1 of Chapter 10, such as function and task analysis, testing, evaluation by simulation, and the use of applicable EPRI guidance documents such as EPRI NP-3659. The staff finds these requirements consistent with accepted human factors principles and practices and the guidance in Section 18.1 of the SRP and Sections 3.7, 6, and B4.4 of NUREG-0700. However, the staff's evaluation of these requirements raised questions regarding the intent of some of the more specific requirements in Section 4 of Chapter 10 of the Evolutionary Requirements Document.

Section 4.4.4 of Chapter 10 specifies that position indication will be provided for all valves at the location where they are controlled. Yet the original version of this same requirement later stated, "Position indication for manually operated valves may be provided if required by the analysis of functions and tasks." This could be misinterpreted to allow some manual valves to have no position indication if not required by functions and task analysis. In its response dated January 24, 1992, to the DSER for Chapter 10, EPRI stated that the third sentence of Section 4.4.4 would be changed to read, "Remote position indication for manually operated valves may be provided if required by the analysis of functions and tasks." It is the staff's position that all valves should have position indication. Therefore, the applicant for FDA/DC should develop design requirements to ensure that valve position indication is provided for all valves, including manual valves, at any location where the valves can be controlled and, in addition, at any location where function and task analysis suggests it is necessary to provide assurance of proper system alignment.

Section 4.5.5 of Chapter 10 specifies that controls of plant components and systems on the main control room workstations are normally to be electronic or "soft" controls, such as touch screens or other non-hard-wired devices, except if there are specific requirements to the contrary. Section 4.4.5 originally stated that, where applicable, the "soft" controls are to meet established human factors guidelines and, in addition, are to meet the requirements of Section 4.5.5 of Chapter 10. Section 4.1.5.2 requires the M-MIS designer to develop the necessary design practices based on the best available information on new technology, such as "soft" controls, for which published guidance on human factors practice is limited. In its response dated January 24, 1992, to the DSER for Chapter 10, EPRI reworded Section 4.5.5 to resolve the ambiguity introduced by the term, "where applicable." The section (Revision 4) now states that where there are established human factors guidelines for "soft" controls, the guidelines will be met. The staff finds the reworded paragraph acceptable.

Section 4.7.4 of Chapter 10 specifies that control stations will be provided with lighting that can be adjusted by the operators to provide uniform illumination in the range of 10 to 50 foot-candles. The rationale used to support this requirement references an EPRI pilot research study, EPRI NP-5989, "Effects of Control-Room Lighting on Operator Performance, A Pilot Empirical Study," which indicates that relatively low lighting levels may be completely adequate (10 foot-candles) and may be preferred by some operators. However, the guidance in Section 6.1.5.3 of NUREG-0700 concerning recommended illumination levels for task performance prescribes minimum levels of 20 to 50 foot-candles and maximum levels of 50 to 100 foot-candles, depending on the type of task. Only in situations where emergency lighting is in use are minimum illumination levels as low as 10 foot-candles recommended. In its response dated January 24, 1992, to the DSER for Chapter 10, EPRI stated that Section 4.7.4 of Chapter 10 was intended to ensure that workstations have lighting that can be adjusted over the identifiable range. EPRI also stated that it was prudent to build in the capability for adjustability and for the potential use of lower light levels rather than having to add the feature at a later time. The staff concludes the new display technologies being considered for evolutionary designs may in fact become a driver for adjusting the overall illumination levels in the control room. However, the staff position is that the results of a pilot empirical study are an insufficient basis for deriving requirements for adjusting the level of illumination at control stations. Therefore, the applicant for FDA/DC should provide documentation substantiating deviations from NUREG-0700 for levels of illumination in the control room.

3.4 Development of Plant Procedures

Consistent with the guidance in Section 13.5.2 of the SRP and Section B4.3.2.9 of Appendix B to NUREG-0700, the staff has taken the position that the methods and criteria used to develop plant procedures and operator aids, including software programs, should be in accordance with valid human factors principles and practices. These procedures should provide guidance for plant operation, maintenance, test, and surveillance during all plant operational modes and conditions.

Section 8.2.2.1 of Chapter 1 of the Evolutionary Requirements Document requires that procedures and training for operation and maintenance be standardized. Also, the designer should develop a standard set of operating and maintenance procedures and training for each ALWR design and should address standardization between ALWR designs to the extent practicable.

Sections 3.1.3.3.3, 3.1.3.5.1, 3.4.2, 3.4.2.1, and 4.1.6.4 of Chapter 10 establish requirements for the development, verification and validation, and documentation and review of operating procedures. These activities will be accomplished using the function and task analysis, the plant dynamic model and simulator, and the control station(s) design documentation. The rationale used for these requirements is that procedures are an integral part of the M-MIS design, and it is inconsistent with the ALWR goals of improving the man-machine interface and standardization to leave the preparation of procedures to individual utilities.

Section 3.1.3.6.2 of Chapter 10 specifies that the designer will prepare inservice surveillance testing procedures that will be used in walk-throughs in control station mockups.

Sections 3.4.2.2 and 3.4.2.2.1 of Chapter 10 require that main control room operator workstations and other workstations that use electronic, selectable displays have electronically displayed procedures, where practicable. The M-MIS designer will establish and document procedure displays and preparation practices and guidelines and use active simulation to validate them. Similarly, Section 3.4.2.3 specifies that hard-copy procedures will be supplied if electronically displayed procedures are not practicable. The designer will establish preparation and practice guidelines for hard-copy procedures using active simulation, and these procedures will be consistent in format and content with electronically displayed procedures. The stated rationale for the use of electronically displayed procedures is based on the experience of Electricite de France.

The information EPRI has provided in Chapter 10 of the Evolutionary Requirements Document concerning the use of electronically displayed procedures is not sufficient for the staff to determine if these requirements are adequate to ensure the development of procedures for safe operation of an ALWR. Although electronic display of procedures may enhance flexibility in information displays, the limitations and constraints associated with this technology, as well as operability, maintainability, and reliability considerations, should be fully evaluated by the designer in the context of the entire control room and other control stations before committing to such an approach. In its response dated February 3, 1992, to the DSER for Chapter 10, EPRI stated that the ALWR program must take a strong position on the use of electronic procedures or the opportunity for a major improvement in plant operability could be lost. The staff agrees with EPRI that the use of electronic procedures presents the potential for being a valuable operator aid and should be explored. However, it believes that the implementation of electronic procedures will require further development to ensure their effectiveness in an actual plant design. To state the use of electronic procedures as a requirement for evolutionary plant control rooms at this time appears to be premature. Therefore, the applicant for FDA/DC should justify using electronically displayed procedures as part of the specific design proposal.

Section 3.4.5 of Chapter 10 requires that the M-MIS design include the definition of the features that are provided to assist the operator in carrying out specific tasks. Operator aids will be considered as an integral part of the overall M-MIS design and will be included in all evaluations of control stations and M-MIS designs.

Section 3.7.7 of Chapter 10 establishes the requirements for maintenance human factors, but does not include requirements for the development, review, and verification and validation of maintenance procedures as part of the M-MIS design. This is inconsistent with the requirements in Section 8.2.2.1 of Chapter 1 of the Evolutionary Requirements Document for the development and standardization of maintenance procedures for each ALWR design. In its response dated February 3, 1992, to the DSER, EPRI stated that Section 3.7.7 of Chapter 10 was intended to be consistent with Section 8.2.2.1 of Chapter 1. The staff concludes that this response is acceptable.

The staff concludes that the requirements in the Evolutionary Requirements Document for the development of procedures are consistent with accepted human factors principles and practices and the guidance in Section 13.5.2 of the SRP and Section B4.3.2.9 of Appendix B to NUREG-0700 and are, therefore, acceptable.

3.5 Personnel Selection and Qualification

On the basis of accepted human factors principles and practices, the staff's position is that the methods and criteria used to select plant personnel, including aspects such as selection criteria, testing, and evaluation techniques, should be based on a systematic function and task analysis.

Section 8.2.6.5 of Chapter 1 of the Evolutionary Requirements Document contains requirements for personnel and staffing. Generally, the requirements allow the plant designer and constructor to assume that personnel staffing for plant operation and maintenance will be defined very soon after the commitment to build an ALWR. The requirements call for staffing the two top echelons of management with people who have held responsible line-management positions for at least 4 years in an operating commercial nuclear power plant. Personnel selected and trained for the plant operating organization will meet the latest version of American National Standards Institute/American Nuclear Society (ANSI/ANS) 3.1, "Selection, Qualification and Training for Nuclear Power Plants."

Section 4.2.6 of Chapter 10 of the Evolutionary Requirements Document requires that the training, qualifications, and experience of the operating staff members, which will be used in the development of the M-MIS design, are to be based on current operating practice, where practicable. Additionally, the M-MIS designer will specify, early in the design process, any levels of training, qualification, and experience of these operating staff members that differ from typical plant owner training and operating practices. These differences and their bases will be included in the M-MIS design documentation.

Section 3.7.7.1 of Chapter 10 specifies that the M-MIS designer will systematically identify the tasks required to maintain the M-MIS equipment, including, for example, definition of skills, tools, test equipment, and access. The rationale used for these requirements is that the plant owner will need to know the qualifications of maintenance personnel and the support and test equipment necessary to maintain M-MIS equipment in operation. Section 3.7.7.4 specifies that M-MIS cabinets will be designed to facilitate access by maintenance personnel. The design of M-MIS cabinets should allow specialized maintenance technicians to work on their particular equipment without interfering with technicians servicing other equipment.

The Evolutionary Requirements Document does not specify that the selection and qualifications of plant personnel, including aspects such as selection criteria, testing, and evaluation techniques, will be based on a systematic function and task analysis. Rather, it appears that selection of both operational and maintenance personnel will be based on assumed existing nuclear plant owner's practice regarding training, qualifications, experience, and skill levels that may not be applicable to ALWR designs. In its response dated January 24, 1992, to the DSER for Chapter 10, EPRI stated that Section 3.1.3.3.3 of Chapter 10 requires the use of functions and tasks to evaluate operator workloads and the mental and physical burdens of the operators. The staff interprets this to mean that the selection and qualifications of plant personnel will be based on a systematic function and task analysis. The staff finds this position acceptable.

The top-level personnel and staffing requirements of Section 8.2.6.4 of Chapter 1 were not reiterated and expanded in Chapter 10. In its response dated January 24, 1992, EPRI stated that specification of the requirements for the plant staff was not within the scope of the Evolutionary Requirements Document. The staff concludes that the resolution of the issues regarding plant staffing is the responsibility of the combined license applicant under 10 CFR Part 50 and will be reviewed by the staff at the combined license stage.

3.6 Personnel Training and Testing

Consistent with the guidance in Section 13.2 of the SRP and Section B4 of Appendix B to NUREG-0700 and accepted human factors principles and practices, the staff has taken the position that the methods and criteria used to train plant personnel and evaluate their job performance, including simulator training, should be based on a systematic function and task analysis. Elements of the human factors program for personnel training and testing should include, as a minimum, the following:

- job-specific analysis
- description of standardized training programs
- identification of approaches and applications of training to be conducted in conjunction with onshift activities or ancillary training
- development of a standardized plant reference training facility
- suggested site functional organization including interfaces

- utility and licensee interfaces for organizational structure and composition of plant staff

Section 8.2.2.1 of Chapter 1 of the Evolutionary Requirements Document specifies that the designer will develop and standardize training for operations and maintenance personnel for each ALWR. Section 8.2.6.5 of Chapter 1 also requires that appropriate personnel from the plant operating organization participate in an owner-developed training program. The training program will provide knowledge of the design basis of the plant and the implementation plan for the project. In addition, personnel selected and trained for the plant operating organization will meet the requirements of the latest version of ANSI/ANS 3.1.

Section 3.1.3.3.3 of Chapter 10 of the Evolutionary Requirements Document specifies that the M-MIS designer will use identified functions and tasks in the development of training requirements and verification and validation reviews.

Section 3.4 of Chapter 10 requires the M-MIS designer to explicitly consider the actions of the operators and other members of the plant staff to operate and control the plant. These actions will be within the capability of all operators. Section 3.4.1.1 requires that the M-MIS design not cause the operators to perform tasks that are beyond their capabilities and that compliance with this requirement be confirmed by dynamic simulation of the tasks in a full-scope simulator. In addition, the M-MIS designer will specify which operator workload measures will be used in the design plan and provide justification for their use.

Sections 3.7.7.1 and 3.7.7.2 of Chapter 10 specify that the M-MIS designer (1) will systematically identify the tasks required to maintain the M-MIS equipment, including, for example, definition of skills, tools, test equipment, and access, and (2) will evaluate the maintenance tasks to ensure that required maintenance actions are simple, well understood, and within the expected capability of maintenance technicians. The evaluations will include the use of mockups or prototypes of typical M-MIS equipment and the performance of maintenance task walk-throughs.

Section 4.2.1.1 of Chapter 10 requires that the M-MIS designer specify the responsibilities assumed in the design for each member of the operating crew. This includes responsibility for supervision and consideration of all plant operating modes and conditions. This information is needed by the plant owner for staffing the plant and planning for training.

The Evolutionary Requirements Document contains requirements for the analysis and evaluation of operator and maintenance personnel tasks and operator workload and states that the results of these analyses and evaluations will be reviewed and verified on mockups, prototypes, and simulators. A requirement for the specification of the operating crew and supervisory responsibilities, to be used for plant staffing and planning of training, is also included. The staff concludes that these requirements are consistent with accepted human factors principles and practices and are, therefore, acceptable.

However, the Evolutionary Requirements Document does not include requirements for (1) descriptions of standardized training programs, (2) the identification of approaches and applications of training to be conducted in conjunction with onshift activities or ancillary training, (3) the development of a standardized plant reference training facility, (4) a suggested site functional organization including interfaces, and (5) utility and licensee interfaces for the organizational structure and composition of the plant staff. Therefore, the applicant for FDA/DC should provide additional guidance to address the top-level personnel training requirements of Sections 8.2.2 and 8.2.6.5 of Chapter 1 of the Evolutionary Requirements Document.

3.7 Human Factors Tests and Evaluations

Section B4.4 of Appendix B to NUREG-0700 and accepted human factors principles and practices form the basis for the staff's position that human factors tests and evaluations should be performed as part of an integrated effort within the total test and evaluation program. Human factors test and evaluation activities should include, as a minimum, the following elements:

- development of a human factors verification and validation test plan
- a method of documenting test activities to provide traceability and ensure that all human factors requirements are addressed during the test and evaluation
- testing of a fully operational control room prototype to determine if the performance objectives of the plant can be met given the equipment design, software design, procedures, training, and organization and staffing complement
- development of quantitative measures to assess human-system performance
- description of how the program will determine if undesirable design or procedural features have been introduced during the design process
- a plan for handling the resolution of problems uncovered during the test phase

The Evolutionary Requirements Document addresses portions of several of these elements in several places. The staff's evaluation of these elements follows.

3.7.1 Development of a Human Factors Verification and Validation Test Plan

The original version and Revision 1 of Chapter 10 of the Evolutionary Requirements Document did not include a requirement for the development of a human factors verification and validation test plan. In its response dated December 6, 1990, to a request for additional information dated August 30, 1990, EPRI committed to add to Section 11.8.5 of Chapter 1, a requirement that the ALWR design development plan specifically identify the features that have been incorporated to ensure a systematic consideration of human factors in the design process. The requirement will specify that the plant designer is to use EPRI NP-3659 and NP-4350 as guidance to determine the features that must be included in the design development plan to address human factors. However, it was not clear to the staff if this requirement will include the development of a human factors verification and validation test plan. In its response dated February 3, 1992, EPRI stated that it was its intent that the M-MIS test plans required by Section 3.1.3.6.1 of Chapter 10 include testing that is necessary to substantiate that human factors considerations have been properly considered in the design. Changes were made to Section 11.8.5 of Chapter 1 and Section 3 3.6.1 of Chapter 10 to reflect EPRI's intent. The staff finds that these changes address its concern and are, therefore, acceptable.

3.7.2 Documentation of Test Activities

Section 3.1.3.5.1 of Chapter 10 requires that the M-MIS design process include the development of digital computer-based dynamic models for the overall plant responses as well as individual control systems, including operator actions. These dynamic models will be completely documented, and the documentation will be provided as part of the final M-MIS design.

Sections 3.1.4.4.1 and 3.1.4.4.2 of Chapter 10 require that the review team include in its review the M-MIS system functional requirements, the system functional designs, and the hardware and software specifications. The review team is also required to confirm and concur that the functional design and specifications will meet plant system functional requirements and will result in satisfactory implementation of the functional design. During these reviews, the review team will also consider human factors aspects of the design. In the DSER for Chapter 10, the staff concluded that EPRI should clarify if these requirements were intended to (1) include a method of documenting human factors test activities to provide traceability and (2) ensure that all human factor requriements are addressed during test and evaluation. In its response dated February 3, 1992, EPRI stated that the review team will document human factors tests in the same manner as any other testing to support the M-MIS design and will document and reference the results so that the basis of the design can be traced. EPRI modified Sections 3.1.4.4.4 and 3.1.4.4.5 to reflect this position. The staff finds that these changes address its concern about documentation of the human factors tests and are, therefore, acceptable.

3.7.3 Testing of a Fully Operational Control Room Prototype

Section 11.10.4 of Chapter 1 specifies that the plant designer is to provide a plant simulator and performance model that can be used as a design tool for studying plant responses and human engineering aspects of the plant controls and control room design and for developing plant operating procedures for normal, abnormal, and accident events.

Section 3.1.3.5.1 of Chapter 10 requires that the M-MIS design process include the development of digital computer-based dynamic models for the overall plant response as well as individual control systems, including operator actions. These dynamic models will be

- suitable for analyzing both steady-state and transient behavior
- used to confirm the adequacy of control schemes
- used to confirm the allocation of control to an automatic system or an operator
- used to develop and validate plant operating procedures
- validated against tests of actual plant behavior wherever practicable

- developed early enough in the design process that modifications of the systems themselves can be made, if shown to be needed by the analysis

- incorporated, as directly as possible, into plant general-purpose or limited-use simulators

- completely documented and the documentation provided as part of the final M-MIS design

The staff finds that these requirements are consistent with the guidance in Section B4 of Appendix B to NUREG-0700 and accepted human factors principles and practices and are, therefore, acceptable.

3.7.4 Development of Quantitative Measures To Assess Human-System Performance

Sections 3.4.1.1 and 3.7.7.2 of Chapter 10 require that the M-MIS design not cause operators and maintenance personnel to perform tasks that are beyond their capabilities. Compliance with these requirements will be confirmed by dynamic simulation of the operator's tasks in a full-scope simulator and maintenance task walk-throughs on mockups or prototypes of typical M-MIS equipment by maintenance personnel.

Section 3.4.1.3 of Chapter 10 requires that the M-MIS design include features that support and facilitate a team approach. These include features that enhance team communications and cohesion and enable the team members to support and back each other up. These features will be based on available information at the time the M-MIS is designed. The basis for these features will be part of the M-MIS design documentation.

Section 4.9.3.8 of Chapter 10 states that any action taken to enable a remote shutdown station or transfer of control to it will be annunciated in the main control room (MCR). The M-MIS designer will determine, using analysis and active simulation, if the annunciation in the MCR provides adequate time for operators and plant security personnel to take action to prevent an accident in the case of unauthorized use of a remote shutdown station.

Section 4.9.4.1.1 of Chapter 10 establishes the requirements for access between the MCR and the technical support center (TSC). The intent of these requirements is to facilitate easy access between the MCR and the TSC during emergencies, to put less burden on voice communications, and to discourage people from congregating in the MCR and disrupting operations. Easy access between the two spaces will facilitate the support of the operators and the "team" approach to coping with emergencies.

The EPRI requirements focus on design considerations, limited assessments, and tests that address operator performance and maintenance tasks. Team performance is only addressed as a feature that must be considered during the design process. In its response dated February 3, 1992, EPRI stated that it has been its experience in human factors research that quantitative measures are not generally well enough established so that they can be applied to such complex issues as team performance. The staff's position is that some form of quantitative assessment of individual and team performance is appropriate to determine if new control rooms will maintain the current levels of operator performance, but perhaps more importantly, will not degrade operator performance. Therefore, the applicant for FDA/DC should develop quantitative measures to assess team performance that would include, for example, verification that the expected interaction between MCR operators and personnel staffing the TSC and emergency operations facility working as a team is achieved.

3.7.5 Determination of Undesirable Design or Procedural Features and Resolution of Problems Uncovered During the Test Phase

Sections 3.1.3.5.1, 3.1.4.4.1, 3.1.4.4.2, and 3.1.4.4.6 of Chapter 10 require the development of digital computer-based dynamic models for overall plant response as well as individual control systems, including operator actions, and the review and documentation of the functional requirements and the human factors aspects of the hardware and software specifications. Sections 4.1.3.2 and 4.1.3.3 require that the design review process provide for the fabrication of a markup of each control station and the use of active simulation of the control station. The mockup of the control station will be fabricated early in the design process so that the results of evaluations can be used to modify the M-MIS and plant system designs. Section 4.1.4 of Chapter 10 of the Requirements Document requires that the control station design process provide for the iteration of functions, tasks, and design assigned to the control station. The design process will specifically provide for feedback, from the design of the individual control stations to the overall identification of functions and tasks and their assignment to particular control stations. The rationale for this requirement provides a means for resolving difficulties found during the review by the reassignment of tasks. The staff concludes that these requirements are consistent with the guidance in Section 18.1 of the SRP, Sections 3.6, 3.7, 3.8, 3.9, 4, and B4.4 of NUREG-0700, and accepted human factors principles and practices and are, therefore, acceptable.

3.7.6 Human Factors Open Issues Originating From Other Chapters

Acoustical Monitoring

In the DSER for Chapter 1, the staff identified acoustical monitoring as an open issue. Originally Section 8.2.4.4.3 of Chapter 1 stated, "The design of the plant shall consider both reduction and attenuation of noise sources to reduce operator noise exposure to levels of Occupational Safety and Health Act [OSHA] standards." The staff does not agree with this position. Noise levels specified by OSHA are the maximum permissible levels of exposure before physical impairment or damage occurs. The noise levels in the control room, remote shutdown panel, and other normally occupied areas should be determined by the accuracy of the communications required within those areas. Areas should be designed so that the acoustic environment will not cause personal injury, interfere with voice or other communication, cause fatigue, or degrade the overall effectiveness of the human-system interaction. For example, within the spaces of the control room, a maximum sound level (A scale) or the corresponding speech interference level could be prescribed. For areas not frequently occupied, or where critical conversations and communications do not occur, the A scale sound levels or the corresponding speech interference levels may be significantly higher. The staff concludes that the applicant for FDA/DC should identify and describe the acoustical environments in the control room, the remote shutdown panel area, and at local control stations. On the basis of above considerations, this DSER open issue is closed.

Reference to Institute of Electrical and Electronics Engineers P1023/D5 and EPRI NP-2360

In the DSER for Chapter 1, the staff recommended that EPRI include IEEE P1023/D5, "Guide for the Application of Human Factors Engineering to Systems, Equipment and Facilities of Nuclear Power Generating Stations," as a reference. It also recommended EPRI NP-2360, "Human Factors Methods for Assessing and Enhancing Power Plant Maintainability," as an excellent reference. The staff identified referencing of these documents as an open issue. In its response dated May 17, 1991, to the DSER for Chapter 1, EPRI stated that Chapter 6, Section 2.1.1, referred to EPRI NP-4350, "Human Engineering Design Guidelines for Maintainability." However, it did not state that it intended to include the IEEE standard as a reference. It is the staff's position that IEEE P1023/D5 should be included as a reference document because, unlike EPRI reports, IEEE documents are periodically updated. Therefore, the applicant for FDA/DC should include IEEE P1023/D5 as part of its design reference documentation. This DSER open issue is closed.

Illumination Levels of Emergency Lighting Systems

In its response dated February 3, 1992, to the DSER for Chapter 11, EPRI stated that Section 8.5.1, Chapter 11, Revision 3, had been modified. The requirement now provides fc emergency illumination of 10 foot-candles at all workstations in the plant where emergency operations will be performed that could require the reading of printed or written material or legends or scales. The staff finds the modification acceptable. Therefore, this DSER open issue is closed.

Man-Machine Interface Requirements Specific to Fueling or Refueling Equipment

In the DSER for Chapter 7, the staff identified man-machine interface requirements specific to fueling and refueling equipment as an open issue. One of the goals of Chapter 7, as stated by EPRI, was to eliminate the man-machine interface problems that exist in past and present refueling equipment designs by emphasizing features that simplify the interaction between the operator and the equipment. In it's letter dated August 30, 1990, the staff requested additional information regarding EPRI's approach to incorporating human factors considerations into the Evolutionary Requirements Document. By letter dated September 7, 1990, EPRI revised Section 3.1.1.2 of Chapter 10 to require that the M-MIS design process be fully integrated with the design processes used for the remainder of the plant. The process will assure that all modes of operation, including refueling, are considered. The staff interprets this to mean that the human engineering requirements specific to fueling and refueling will be considered. The staff finds this approach acceptable. Therefore, this DSER open issue is closed.

4 CONCLUSION

The staff concludes that the human factors requirements in the Evolutionary Requirements Document are consistent with accepted human factors principles and practices and do not conflict with current regulatory requirements and guidance. They are, therefore, acceptable. However, by themselves, they do not provide sufficient information for the staff to determine if an ALWR design referencing the Evolutionary Requirements Document will adequately incorporate human factors considerations in a manner that will achieve safety and reliability and ultimately reduce the probability of human error. Therefore, applicants referencing the Evolutionary Requirements Document will be required to provide sufficient information, as indicated in the previous sections, to demonstrate that their human factors program will ensure that the level of human performance required to maintain plant safety is achieved.

The staff concludes that the Evolutionary Requirements Document specifies human factors requirements that, if properly translated into a design in accordance with the NRC regulations in force at the time the design is submitted, should result in an acceptable nuclear power plant design.

APPENDIX E
OPTIMIZATION SUBJECT

In the DSER for the original version of Appendix E to Chapter 10, the staff provided its evaluation of an optimization subject related to EPRI's proposal to eliminate the requirement for a reactor vessel level instrumentation system (RVLIS). In response to the DSER for Chapter 10, EPRI has reconsidered its position and has provided it requirements for a RVLIS in the Evolutionary Requirements Document. Therefore, this is no longer an optimization subject. The staff's evaluation of the RVLIS is provided in Section 6.3 of Chapter 4 of this report.

CHAPTER 11, "ELECTRIC POWER SYSTEMS"

1 INTRODUCTION

This SER documents the NRC staff's review of Chapter 11, "Electric Power Systems," of the "Evolutionary Requirements Document" through Revision 3. Chapter 11 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering Nuclear Power; Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Incorporated; Sargent and Lundy Engineers; Science Applications International Corporation; Westinghouse Electric Corporation; and EPRI.

On April 10, 1989, EPRI submitted the original versions of Chapter 11 of the Evolutionary Requirements Document for staff review. The staff requested additional information in a letter dated April 10, 1990. EPRI submitted additional information in letters dated September 15, October 19, and December 22, 1989, and July 23, 1990. Topic papers in Appendix B of the original version of this chapter were relocated to Appendix B of Chapter 1.

On April 3, 1991, the staff issued its DSER for Chapter 11 of the Evolutionary Requirements Document. On May 29, 1992, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 11, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 11, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992 respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 11 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 11

Chapter 11 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the electric power systems.

The key topics addressed in the Chapter 11 review include EPRI-proposed design requirements for the

- offsite power system
- medium- and low-voltage ac distribution systems
- onsite standby ac power supply system
- dc and low-voltage vital ac power supply systems
- normal and emergency lighting
- electrical protective systems

1.3 Policy Issues

During its review of Chapter 11 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 11 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) human factors (2.1)

(2) environmental qualification test criteria for electrical power systems (2.2)

(3) use of Institute of Electrical and Electronic Engineers (IEEE) standards not approved by the Commission (2.2.7)

(4) alternate source of power for non-safety loads (4.2.1)

(5) offsite power source for safety bus (4.2.2)

(6) security considerations for the combustion turbine generator (4.2.3)

(7) alternate ac power source (station blackout considerations) (5.2.2)

(8) load capability of combustion turbine generator (5.2.3)

(9) power rating of diesel generators (5.2.4)

(10) loading logic to respond to loss-of-coolant-accident/loss-of-offsite-power sequences (5.2.5)

(11) loss of power to a dc bus (7.2.1)

(12) design of lighting systems in safety-related areas and access routes to those areas (8.2.1 and 8.2.2)

(13) illumination level of emergency lighting system (8.2.3)

(14) qualification and redundancy of emergency lighting system (8.2.3)

(15) control and mitigation of transformer fires (Generic Safety Issue 107)

(16) electrical power reliability (Generic Safety Issue 128)

Confirmatory Issues

(1) safety classification of loads (2.2.1)

(2) vital area access during emergency conditions (2.2.2)

(3) power rating of diesel generators (5.2.4)

(4) uninterruptible power supply for security equipment (7.2.3)

(5) compliance of emergency lighting with Standard Review Plan (NUREG-0800) and applicable codes (8.2.3)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All issues identified in the DSER for Chapter 11 have been resolved.

1.5 <u>Vendor- or Utility-Specific Items</u>

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant options. The first number designates the chapter in which it is identified. The letter V designates that it is a vendor- or utility-specific item. The final number provides the sequential number assigned to it in the chapter.

<u>Vendor- or Utility-Specific Issues</u>

E.11.V-1 environmental qualification test criteria for electrical power system (2.2)

E.11.V-2 safety classification of loads (2.2.1)

E.11.V-3 minimization of Class 1E components (2.2.4)

E.11.V-4 instrumentation and controls for electric motors (2.2.5)

E.11.V-5 compliance with NFPA Codes and Standards (2.2.6)

E.11.V-6 integrity of electrical cable penetration seals during a fire (2.2.6)

E.11.V-7 integrity of bus duct penetrations during a fire (2.2.6)

E.11.V-8 review of IEEE standards not endorsed by regulatory guides (2.2.7)

E.11.V-9 review of the actual setpoint criteria used for sizing thermal overloads (2.2.7)

E.11.V-10 limitation of total voltage distortion to 3 percent (4.2.4)

E.11.V-11 effects of electrical faults on the coastdown capability of the reactor coolant pumps and reactor internal pumps (4.2.5)

E.11.V-12 use of combustion turbine generator as alternate power source during shutdown (5.2.1)

E.11.V-13 continuous rating versus short-term rating for sizing the combustion turbine generator (5.2.3)

E.11.V-14 inclusion of the pressurizer heaters in the diesel generator power analysis (5.2.4)

E.11.V-15 continuous rating of the diesel generators to include emergency lighting (5.2.4)

E.11.V-16 capability of the diesel generators to power safety buses in a protected bus configuration (5.2.5)

E.11.V-17 emergency diesel engine starting system (5.2.6)

E.11.V-18 emergency diesel engine fuel oil storage and transfer system (5.2.6)

E.11.V-19 allowed outage time for load center (6.2)

E.11.V-20 impact of loss of ac or dc bus on single-failure protection in safety-related systems (7.2.1)

E.11.V-21 outage time for dc safety buses in a BWR plant design (7.2.2)

E.11.V-22 common backup ac power sources for safety-related uninterruptible power supplies (7.2.4)

E.11.V-23 design of the continuous ac lighting in safety-related areas and access routes outside the main control room (8.2.1 and 8.2.2)

E.11.V-24 method of integrating the emergency lighting system with the normal lighting in the main control room (8.2.3)

E.11.V-25 acceptability of lighting system for closed-circuit television system (8.2.4)

2 GENERAL REQUIREMENTS AND POLICY STATEMENTS

2.1 Policy Statements

Section 1.5 of Chapter 11 of the Evolutionary Requirements Document identifies EPRI's policy statements that form the basis for the specific design requirements in Chapter 11. Section 1.5.1 of Chapter 11 states that the overall objective of the design features specified in the chapter is to achieve the goals described in Section 1 of Chapter 1 of the Evolutionary Requirements Document.

Section 1.5.2 of Chapter 11 states that the plant designer should adopt design features, including the necessary redundancy and backup features, that will ensure that the adverse effect of transmission system disturbances, plant upsets, or component failures on the availability of offsite or onsite electric power will be kept to a minimum. The document further directs the designer to improve the testability and maintainability of the electric power systems in order to maximize equipment reliability.

Section 1.5.3 of Chapter 11 states that the minimum number of components and interconnections required to provide the backup and redundancy features needed for safety and availability purposes will be used in the design of electric system configurations.

Section 1.5.4 of Chapter 11 defines general system configurations for the offsite and onsite electric power systems that will suit the needs of most plants because electric power systems are not standardized among nuclear power plants in the United States. EPRI states that changes to the general configurations specified in Chapter 11 will be limited to only those forced by specific, unusual site conditions.

In Chapter 1 of the Evolutionary Requirements Document, EPRI states that it has considered the man-machine interface in its development of the design requirements in all of the chapters of the document. The staff identified this as an open issue in the DSER for Chapter 11. The staff's evaluation of EPRI's requirements for human factors considerations is provided in Appendix D to Chapter 10 of this report. Therefore, this DSER open issue is closed.

2.2 General Requirements

The requirements in Section 2 of Chapter 11 of the Evolutionary Requirements Document are intended to apply to an integrated set of electric power systems for an evolutionary ALWR plant design.

Section 2.3.2 of Chapter 11 describes a three-tier concept for the arrangement of the onsite power distribution systems. The first-tier distribution systems will feed non-safety loads required exclusively for unit operation; the second tier will feed permanent non-safety loads that, because of their specific functions, are generally required to remain operational at all times; and the third tier will feed the safety (Class 1E) loads. The non-safety power distribution systems (first and second tiers) will be divided into two divisions. Section 2.3.5 of Chapter 11 specifies that the safety power distribution systems (third tier) will be divided into two independent divisions for PWR plants and three independent divisions for BWR plants. The non-safety power distribution systems (second tier), supplying power to the plant's permanent non-safety loads, will be provided with an independent onsite standby power source (combustion turbine generator). Each division of the safety power distribution systems (third tier) will be provided with independent onsite standby power sources (diesel generators).

Section 2.3.10 of Chapter 11 states that the sets of circuits that constitute the divisions of the safety power distribution systems will be physically separated and electrically independent. Independence and separation will be maintained throughout the load groups, and no cross-ties will be used between buses or circuits (ac or dc) belonging to different safety divisions.

Section 2.3.11 of Chapter 11 states that non-safety circuits will be physically separated from safety circuits throughout the plant, and non-safety circuits will not be permitted to be connected to safety circuits or power sources.

Section 2.6.1.7 of Chapter 11 specifies that electric power systems will be designed for a 60-year operating life without replacement of major components or cabling. However, the design of the systems and the building arrangement will permit such replacement, if needed. The staff determined that the Evolutionary Requirements Document did not specify test criteria to ensure that the electrical power systems will be qualified for a 60-year service life without replacement of major components or cabling. Therefore, the DSER for Chapter 11, it concluded that EPRI should include such equipment qualification test criteria for these electrical power systems and identified this as an open issue.

In response to the DSER open item, EPRI stated that qualifications testing for the electric power systems is required by referenced Institute of Electrical and Electronics Engineers (IEEE) 323, 334, 344, and 383. Sections 2.6.1-1, 2.6.1-3, 2.6.2-4, and 2.6.3-3 of Chapter 11 require that equipment qualification criteria for all ALWR electric power systems meet the IEEE standards. However, the IEEE standards do not require a 60-year service life for the qualified systems. To address this concern, EPRI revised Section 3.3 of Chapter 1 of the Evolutionary Requirements Document to state that ALWR plants will be designed for 60 years of operation without the need for an extended refurbishment outage and to permit expeditious component replacement for obsolescence and failure over a lifetime of 60 years. EPRI's rationale for the service life requirement is that the technological maturity of nuclear plants currently being designed is well advanced. Additionally, functional lifetimes of nuclear power plants operated under a planned program for achieving high availability appear to have the capability to exceed the current 40-year-license lifetime by perhaps a factor of 1.5 to 2.0. Therefore, EPRI concludes that a plant lifetime of 60 years appears achievable if the design requirement is addressed throughout the design process.

The requirement in Section 2.6.1.7 of Chapter 11 applies particularly to the main step-up transformers, the unit auxiliary transformers, the unit substation breakers, the standby power sources, and the plant cabling systems, including electrical penetrations. EPRI states that, for components with anticipated short lives (e.g., continuously energized relays and electronic components), the plant designer will determine the probable life expectancies of the components and adopt design provisions to facilitate their replacement. The staff concludes that EPRI's requirement does not conflict with regulatory requirements and is acceptable for non-safety related systems.

The requirements for qualifying Class 1E equipment are given in various standards and regulatory requirements, including 10 CFR 50.49, Appendix A to 10 CFR Part 50, and IEEE standards. Nuclear power plant Class 1E equipment is required to meet or exceed its performance requirements throughout the installed life of the equipment as determined by the applicant for FDA/DC. The IEEE standards are designed for current LWR plants to provide guidance in determining design features and testing related to the electric power systems with a 40-year operating life. However, ALWRs are being designed with longer service lives and may include alternative materials and different design conditions. Consequently, electrical equipment important to safety that is to be demonstrated qualified for operating lives greater than 40 years will be required to be qualified in accordance with 10 CFR 50.49(f), as discussed in Section 4.8.2 of Chapter 1 of this report. The staff will review the specific qualification methods for the future ALWR plants on a plant-specific design basis. The staff concludes that the general requirements provided in the Chapter 11 for qualifying the electric power systems do not conflict with NRC requirements and are acceptable. This DSER open issue is closed.

2.2.1 Three-Tier Concept

Section 2.3.2 of Chapter 11 requires that the arrangement of the onsite power distribution systems follow a three-tier concept. The first tier of systems will consist of the distribution systems feeding non-safety loads required exclusively for unit operation. EPRI designates the normal power source for these systems as the main generator for the unit. These systems will be able to be fed from the offsite power system through a backfeed configuration if the main generator is unavailable.

The second tier will consist of the distribution systems supplying power to permanent non-safety loads that, because of their specific functions, are generally required to remain operational at all times. These loads will normally be fed from the same power source that feeds the first-tier loads. However, they also will be able to be fed from a second independent offsite source or a combustion turbine generator if their normal power source is unavailable. In addition, EPRI specifies that the Class 1E diesel generators will be able to power a portion of the loads, if necessary.

The third tier will consist of the distribution systems feeding the safety (Class 1E) loads. Their normal power source will be the same as that which normally feeds the first- and second-tier systems; however, like the second-tier systems, they will also be able to be fed from the Class 1E diesel generators, a second independent offsite source, or the combustion turbine generator.

By letter dated April 10, 1990, the staff asked EPRI if any of the loads intended to be included in the permanent non-safety-load category (second tier) were formerly categorized as safety loads. In its letter dated July 23, 1990, EPRI stated that the requirements of Chapter 5 of the Evolutionary Requirements Document determine the characteristics of the safety systems for an ALWR plant design and that all loads that are part of those safety systems will be included in the safety category. Loads that are not part of those safety systems will be included in one of the two non-safety categories. EPRI explained that the justification for considering specific systems safety or non-safety is included in the portion of the Evolutionary Requirements Document that defines the requirements for each specific system.

In the DSER for Chapter 11, the staff concluded that the three-tier concept was not intended to be used as a basis for reclassifying former safety loads as non-safety or for supplying safety loads from only a non-Class 1E distribution system and power source (second tier). The staff also concluded that the other chapters of the Evolutionary Requirements Document must clearly define the category (safety or non-safety) of the loads, especially if they have been downgraded from previous designs. The DSER for Chapter 11 stated that the staff would confirm that those descriptions have been provided in the Requirements Document.

In a letter dated November 26, 1991, EPRI indicated that the functions for systems in the Evolutionary Requirements Document are clearly identified as "safety" or "non-safety." Since it will evaluate the acceptable safety classification of these loads as part of its review of individual applications for FDA/DC, the staff concludes that this is acceptable. The staff has confirmed that these descriptions have been provided in the Evolutionary Requirements Document, therefore, this issue is closed.

2.2.2 Security Systems

Sections 2.3.2 and 2.3.4 of Chapter 11 include requirements for supplying power from an independent onsite standby power source to permanent non-safety loads required to remain operational at all times. In the original version of Chapter 11, security systems were listed among the typical loads in this category.

NUREG-0908, "Acceptance Criteria for the Evaluation of Nuclear Power Reactor Security Plans," states that, under an acceptable security program, the alarm stations would typically be provided with a source of emergency power capable of supplying power for all required security functions. American National Standards Institute/American Nuclear Society (ANSI/ANS) 3.3-1988 specifies that security intrusion detection aids should be supplied with uninterruptible power. In the DSER for Chapter 11, the staff concluded that EPRI's requirements were compatible with the NRC requirements for backup power to security systems.

Subsequently, EPRI revised Chapters 9 and 11 of the Evolutionary Requirements Document to specify a separate dedicated onsite security power supply, instead of requiring backup security system power from the plant non-safety standby power source. As discussed in Chapter 9 of this report, the staff concludes that this is acceptable.

Section 2.6.1.5 of Chapter 11 requires seismic protection of non-Class 1E equipment only if it is located in the vicinity of Class 1E equipment or support structures. By letter dated May 24, 1989, the staff requested that EPRI clarify whether non-Class 1E equipment supporting the card reader access control system for vital areas would be required to meet seismic standards in order to ensure access to vital areas after an earthquake. In its letter dated September 15, 1989, EPRI stated that requirements compatible with the requirement of 10 CFR 73.55(d)(7)(ii) for the access control system to accommodate the need for rapid ingress or egress during emergency conditions would be issued in an appendix to Chapter 1 of the Evolutionary Requirements Document. However, specific features of the access control system required to ensure necessary access to vital areas will not be described.

In the DSER for Chapter 11, the staff agreed that means other than seismic qualification, as proposed by EPRI, would be sufficient for ensuring access to vital equipment if the security computer or security power were lost. The staff stated that EPRI's commitment to add an appendix to Chapter 1 was acceptable and that the staff would confirm that these revisions were incorporated into Evolutionary Requirements Document. This was listed as a confirmatory issue in the DSER.

The staff has confirmed that Appendix B to Chapter 1 requires compliance with the requirements of 10 CFR 73.55. Therefore, EPRI's commitment is satisfied and this confirmatory issue is closed.

2.2.3 Number of Safety Divisions

Section 2.3.5 of Chapter 11 specifies that the onsite safety power distribution systems (third tier) will be divided into two separate and independent divisions for PWR plants and three separate and independent divisions for BWR plants. Each division will be required to have its own separate and independent source of emergency standby power.

By letter dated April 10, 1990, the staff asked why three distribution system divisions had been chosen for the BWR plant, while only two had been chosen for the PWR plant. In its letter dated July 23, 1990, EPRI stated that the fundamental reason for the difference between the electrical power systems of the BWR and PWR lies in the differing fluid system designs that result from basic differences in these two types of reactors. It stated that both approaches satisfy all applicable regulatory requirements as well as EPRI's goals with regard to core damage frequency and performance during a severe accident.

The staff concludes that the design for three distribution system divisions is a better approach because any of the required reactor shutdown loads could be powered from any of the three divisions; however, it agrees that both approaches meet all applicable regulatory requirements including General Design Criterion 17 of Appendix A to 10 CFR Part 50 and, therefore, are acceptable.

2.2.4 Minimization of Class 1E Components

Section 2.3.8 of Chapter 11 requires that the number of Class 1E components be kept to a minimum. Equipment or systems that are not essential for emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are not otherwise essential in preventing significant release of radioactive material to the environment, will not be designated Class 1E unless they constitute auxiliary equipment required for the operation of Class 1E components.

In its letter dated April 10, 1990, the staff expressed concern that this requirement could allow non-safety concerns (minimizing qualification, surveillance, and maintenance) to affect safety improvements and could be misinterpreted or abused, resulting in the downgrading of components that had formerly been designated Class 1E. By letter dated July 23, 1990, EPRI responded that the safety systems should be designed for simplicity of operation, surveillance, and maintenance so as to optimize their reliability and address concerns regarding cost. EPRI indicated that higher levels of safety than those in existing plants will be achieved by specifying other safety improvement requirements; therefore, the staff's concern that this approach could lead to a downgrading of safety or performance was incorrect. EPRI also indicated that it believes that it is necessary to have definitive requirements in this area to provide a basis for standardization and to avoid the large number of "custom" designs. Finally, with regard to the staff's position that some level of qualification, surveillance, and maintenance requirements should be specified for some non-safety equipment commensurate with its importance to safety, EPRI stated that the staff had raised a similar concern in the DSER for Chapter 5 of the Evolutionary Requirements Document and that it would address the appropriate level of qualification for specific equipment and systems in that chapter. EPRI stated that Chapter 11 will be revised as appropriate to be consistent with Chapter 5.

The staff disagrees with EPRI that the subject requirement is "definitive" and will lead to a more standardized use of Class 1E and non-Class 1E equipment. Because the requirement is open to interpretation as to what is essential and what constitutes auxiliary equipment required for the operation of Class 1E components, the staff cannot determine the systems or components to which the requirement applies. For example, the staff cannot determine if this applies to the categorization of electrical protective overcurrent relaying and electrical monitoring instrumentation. Also, broad safety goals do not provide adequate assurance of well-designed and well-specified systems at this level of detail. The staff concludes that the resolution of the level-of-qualification issue in Chapter 5 of the Evolutionary Requirements Document will not identify electrical equipment or components down to the level of detail necessary for the staff's review. Therefore, the staff will evaluate the application of this requirement for minimizing of Class 1E components during its review of an individual application for FDA/DC.

2.2.5 Equipment

In its letter dated September 14, 1989, the staff asked a question concerning the electric motor starting voltage requirements of Section 2.6.2 of Chapter 11. In its letter dated December 22, 1989, EPRI stated that the voltage and frequency requirements for the associated instrumentation and control equipment are too specific to be included in the Evolutionary Requirements Document but that the design of power supplies will generally satisfy functional and operational requirements. EPRI's response is not inconsistent with the Commission's regulations and policies and is acceptable. However, the staff will evaluate the voltage and frequency values for the instrumentation and controls for electric motors during its review of an individual application for FDA/DC.

2.2.6 Fire Protection

The staff evaluated the criteria for the fire protection system in the Evolutionary Requirements Document against the criteria of Standard Review Plan (SRP) Section 9.5.1, "Fire Protection Program" (Branch Technical Position CMEB 9.5-1, July 1981) and supplemental guidance issued by the Commission.

Three examples of such supplemental guidance are (1) Generic Letter 81-12, which contains information on safe-shutdown methodology; (2) Generic Letter 86-10, which contains some important technical information such as that pertaining to conformance with National Fire Protection Association codes and standards; and (3) the Commission's staff requirements memorandum dated January 12, 1990, on SECY-90-016, "Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements." The staff discusses criteria and basis for their use in Section 2.5 of the DSER on Chapter 5 and Section 3 of Chapter 9 of this report.

The staff's evaluation of the fire protection system performance requirements in Chapter 11 follows.

EPRI has generally followed NRC's concept of defense-in-depth with regard to fire protection. The three steps of defense-in-depth and EPRI's implementation of these steps follow:

(1) Reduce the possibility of fire starting in the ALWR plant - EPRI specifies that fire-resistant and fire-retardant materials will be used in the design of reactor plants referencing the Evolutionary Requirements Document to minimize and isolate fire hazards. EPRI specifies that either low-voltage or fiberoptic multiplexed circuits will be used in ALWR designs, thus eliminating the need for cable spreading rooms and substantially reducing the amount of combustible cable insulation and higher voltage ignition sources in the control room.

(2) Detect and suppress a fire promptly - EPRI specifies that automatic detection and a suitable mix of automatic and manual fire suppression capability will be incorporated in ALWR designs.

(3) Ensure that any fire that might occur will not prevent safe shutdown of the plant even if fire detection and suppression efforts should fail - EPRI has attempted to ensure this in the Evolutionary Requirements Document.

A detailed evaluation of the effectiveness of this approach is provided below.

The fire protection program described by EPRI is intended to protect safe-shutdown capability, prevent the release of radioactive materials, minimize property damage, and protect personnel from injury as a result of fire.

EPRI considered not only the three aspects of defense-in-depth outlined above, but also such features of general plant arrangement as access and egress routes, equipment locations, structural design features that separate or isolate redundant safety-related systems, floor drains, ventilation, and construction materials.

EPRI specifies that applicable codes and standards of the National Fire Protection Association will be incorporated in the design and layout of an ALWR facility. The staff will review applications for FDA/DC to ensure that an ALWR designers or applicants identify any deviations from these codes and standards and to describe in the fire hazard analysis the deviations and measures taken to ensure that equivalent protection is provided.

Integrity of Electrical Cable Penetration Seals

In its letter of June 8, 1989, the staff stated that it was concerned about ensuring the integrity of the penetration seals that protect openings used for passing electrical cable through fire barriers if cable trays should collapse.

In its letter of October 19, 1989, EPRI stated that it would revise Section 2.6.4 of Chapter 11 to require designers to ensure that seals at locations where cables penetrate fire barriers remain effective should cable trays collapse from the effects of fire. Chapter 10 of the Evolutionary Requirements Document will reference the Chapter 11 design criteria so that it is clear that penetrations of barriers for instrumentation and control cables must meet the same requirements.

The staff concludes that EPRI's response meets the criteria discussed above and is acceptable. However, it will evaluate this issue during its review of an individual application for FDA/DC to ensure the actual design and installation are acceptable.

Integrity of Bus Duct Penetrations

In its letter of June 8, 1989, the staff stated that it was not clear if there would be locations where bus ducts penetrate fire barriers. The staff further requested that EPRI clarify how it proposed to design such penetrations to satisfy the 3-hour-fire rating criterion should such penetrations be allowed in the design criteria.

In its letter of October 19, 1989, EPRI stated that only the isolated phase bus is expected to require air cooling in the design of an evolutionary ALWR and that it will pass through the turbine building wall and connect to an oil-filled transformer located at least 50 feet from the building. EPRI further stated that although it does not expect that a 3-hour-fire rating will be required for this bus duct penetration, the fire hazard analysis required by Section 3.3.2.1 of Chapter 9 of the Evolutionary Requirements Document will assess the adequacy of the turbine building wall.

The staff concludes that EPRI's response meets the criteria discussed above and is acceptable. However, it will evaluate this issue during its review of an individual application for FDA/DC to ensure the actual design and installation are acceptable. In addition, in Section 2.3 of the DSER for Chapter 6 of the Evolutionary Requirements Document, the staff described an open issue regarding the location of oil-filled transformers in relation to exterior building walls. The staff's evaluation of this issue is provided in Chapter 6 of this report. The staff's evaluation of Generic Safety Issue 107, "Generic Implications of Main Transformer Failure," is given in Section 3.2.4.1 of Appendix B to Chapter 1 of this report.

2.2.7 Use of Revisions to IEEE Standards Not Endorsed by the Commission

In a number of sections of Chapter 11, EPRI specifies that the implementation of its requirements will be in accordance with the latest revision of an IEEE standard, as modified by applicable regulations. By letter dated April 10, 1990, the staff indicated that this should be changed so that the implementation of the requirements is in accordance with the latest revision of the IEEE standard that is endorsed by an NRC regulatory guide and modified by applicable regulations. This was considered necessary because the Commission has not endorsed the latest revisions of IEEE standards.

In its letter dated July 23, 1990, EPRI stated that the requirements as written in the Evolutionary Requirements Document indicate that precedence is to be given to regulatory requirements over IEEE standards and reference to the latest revisions of IEEE standards is appropriate because this does not conflict with the commitment to comply with the regulatory requirements but requires compliance with improvements made to the standards.

The explanation provided by EPRI is acceptable to the extent that it indicates that precedence is to be given to regulatory requirements over IEEE standards if there is a conflict between the two. Revisions of an IEEE standard, however, may include unacceptable changes in portions of the previous standard which was endorsed by a regulatory guide, that were not specifically addressed in the regulatory guide, so that a conflict between the regulatory guide and the new standard is not apparent. The revisions also may provide additional detail or information in an area not previously reviewed by the staff or addressed by the regulatory guide. Again, no conflict between the regulatory guide and standard would be apparent.

In the DSER for Chapter 11, the staff concluded that Chapter 11 should be revised to reference only those revisions of IEEE standards that are endorsed by regulatory guides. Alternatively, the latest revision of the IEEE standard may be referenced, provided EPRI stipulates that during the design certification process, the plant designers identify all changes from and additions to the last version of the IEEE standard that was endorsed by a regulatory guide. This was identified as an open issue in the DSER.

In a letter dated November 26, 1991, EPRI revised the Evolutionary Requirements Document to include a statement that applicable structural design and construction codes and industry technical standards that conflict with NRC positions will be resolved by the plant designer with the NRC and the resolution will be documented. The staff will review any such changes and additions for acceptability during its review of an application for FDA/DC. This open issue is closed.

2.2.8 Emergency Response Facilities

In its letter dated May 24, 1989, the staff requested that EPRI clarify which power supply will be used to support the emergency response facilities (ERFs) and to provide the rationale for the assignment of electrical loads to these facilities.

In its letter dated September 15, 1989, EPRI indicated that the power supplies for the ERFs will be designed to meet the criteria in NUREG-0696, "Functional Criteria for Emergency Response Facilities." EPRI stated that the ERF loads are considered permanent non-safety loads that will be able to be fed from either a normal offsite, reserve offsite, or standby onsite non-vital source. Power also will be made available from the onsite safety (Class 1E) power source, if necessary.

The staff concludes that EPRI's response satisfactorily addresses its concern, and is, therefore, acceptable.

2.2.9 Thermal Overload Devices Provided for Protection of Valve Motor Operators

Thermal overload devices are often provided in the electrical circuits of motors to protect the motors against overloading. In the case of intermittent-duty motors used for safety-related valve operators, the staff was concerned that the thermal overloads could result in undesired tripping of the motor if a safety-related valve operation is required. Therefore, the staff issued Regulatory Guide (RG) 1.106, which recommends certain criteria for the design and application of thermal overload devices used for the protection of safety-related valve motor operators. Sections 6.5.2 and 7.6.1 of Chapter 11 provide requirements for the application of thermal overload devices used to protect the ac motors and dc motors of motor-operated valves. In the case of Class 1E motor operators, the requirements specify that proper engineering and thermal overload devices be used to provide maximum operator protection without unacceptably compromising the safety function of the system. The thermal overload devices will be selected and sized according to the latest revision of IEEE 741, "IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations." The devices generally will be used to trip the operator when necessary to prevent motor failure and to produce an alarm indicating misoperation. Bypassing features to restrict operator protection will not normally be provided.

The requirements specified by EPRI in Chapter 11 are generally in agreement with the staff recommendations in Position 2 of RG 1.106, which allows the thermal overloads to be retained if their trip setpoints are established with all uncertainties resolved in favor of completing the safety-related function. Requirements specified for valve motor operators in Section 3.4.12 of Chapter 5 of the Evolutionary Requirements Document, however, contradict the Chapter 11 requirements; although both sets of requirements meet RG 1.106 recommendations. In a letter dated January 10, 1992, EPRI stated that the ALWR approach for providing valve operator protection without compromising the safety functions is described in Chapter 11 and, to eliminate any ambiguity, Section 3.4.12 of Chapter 5 has been deleted. This is acceptable to the staff.

The staff will review the actual setpoint criteria used for sizing the thermal overload devices during its review of an individual application for FDA/DC.

2.3 Conclusion

The staff concludes that the requirements in Section 2 of Chapter 11 of the Evolutionary Requirements Document do not conflict with current regulatory requirements or guidance and are acceptable.

3 OFFSITE POWER SYSTEM

3.1 Functional Description

Section 3.1 of Chapter 11 of the Evolutionary Requirements Document states that the offsite power system will include the set of electrical circuits and associated equipment that will be used to interconnect the offsite transmission system, the main generator of the plant, and the onsite electric power distribution systems. It will include the plant switchyard(s) or remote station(s), the main step-up transformers, the unit auxiliary and reserve transformers, the high-voltage lines, and the isolated phase buses, with their associated auxiliary systems, including protection relays and local instrumentation and controls.

In general, Section 3 of Chapter 11 calls for one offsite power circuit to use the main generator circuit in the backfeed direction from the switching station (plant switchyard or remote station) through the main step-up transformer to the unit auxiliary transformers. EPRI refers to this circuit as the "main offsite power circuit," and it will be the normal source of power for all plant loads (safety, non-safety, and permanent non-safety) during all modes of operation (operating and shutdown). A low-voltage generator circuit breaker will be provided to isolate the main generator from this circuit when the generator is inoperative.

A second offsite power circuit will be provided as a second source of offsite power to only the safety and permanent non-safety loads when the main offsite power circuit is unavailable. EPRI refers to this circuit as the "reserve offsite power circuit." Section 3.3.4 of Chapter 11 requires that the main and reserve offsite power circuits be connected to switching stations that are independent and separate.

3.2 Evaluation

3.2.1 Use of Separate Lower Voltage Switching Station

As stated above, Section 3.3.4 of Chapter 11 specifies that the main and reserve offsite power circuits will be connected to switching stations that will be independent and separate. EPRI states that it takes advantage of the low capacity requirement of the reserve offsite power circuit to connect the circuit to a different transmission system, typically, a local grid of lower capacity and lower voltage than the transmission system to which the main offsite power circuit will be connected.

In a letter dated April 10, 1990, the staff stated that it recognized the benefits inherent in connecting the offsite power circuits to sources that are separate and independent. However, it was concerned about EPRI's use of lower voltage circuits because higher voltage transmission circuits are more reliable than the lower voltage circuits. This is at least partially because of the superior construction and separation used in the higher voltage circuits.

By letter dated July 23, 1990, EPRI stated that the lower voltage circuits were referenced because its review of loss-of-offsite-power events showed that when a separate, independent reserve circuit is provided, it is generally connected to relatively low-voltage, low-capacity transmission lines. EPRI stated that although the overall reliability of the transmission lines will probably not be higher than that of the transmission lines to which the main circuit is connected, the probability of such a reserve circuit remaining energized following a loss of the main circuit is much higher than that of a reserve circuit connected to the same transmission lines as the main circuit. EPRI indicated that this higher conditional availability results mainly from the independence of and the separation between the main and reserve circuits rather than from the characteristics of the transmission lines to which the latter circuit will be connected.

The staff concludes that the higher conditional availability combined with the likely lower normal availability of a separate and independent lower voltage switching station makes it suitable primarily as a standby offsite power source, that is, one that will be used as an alternate offsite power source to power loads only when the normal offsite power source is unavailable. As specified in the Evolutionary Requirements Document, by using separate and independent switching stations of approximately the same voltage and capacity and, assuming everything else is equal, both would be appropriate as normal offsite power sources to plant loads. Therefore, EPRI's response with regard to this matter is acceptable.

3.2.2 Connection of the Offsite Transmission System to the Safety Onsite Power Distribution System

Section 3.2.1 of Chapter 11 states that the safety and non-safety power distributions systems normally will both be fed directly from the main generator (i.e., the power flow path will not go through the switching station) during normal plant operation and following a separation of the plant from the transmission system without turbine trip. Figures 11.2-1 and 11.2-2 of Chapter 11 show this power feed being derived from two unit auxiliary transformers connected to the main generators through a generator breaker. If the generator breaker trips and the main generator is unavailable and isolated, power will be backfed from the switching station through the main step-up transformer to the unit auxiliary transformer. This circuit is called the "main offsite power circuit." The advantage of this configuration is that the normal power supply to the plant auxiliary and safety systems can be supplied continuously and unswitched from the unit auxiliary transformers during and throughout startup, operation, and shutdown of the nuclear generating unit. It avoids the need for fast-transfer schemes on plant trip that have not been reliable and can produce stressful transients on plant electrical equipment.

Nonetheless, the staff has determined that there are some shortcomings with this configuration, including the following:

- The offsite circuit will be connected through the unit main step-up transformer, which EPRI identifies as the main cause of losses of plant availability among the electrical systems at nuclear power plants.

- A trip of the high-voltage main generator circuit breakers in the switchyard causes both a load-rejection event and the simultaneous loss of the main offsite power circuit.

- Reliance will be still placed on the correct actuation of active system components (the low-voltage generator circuit breaker and its related auxiliary support systems, logics, and controls) to maintain operation of the main offsite power circuit following a main generator trip.

- Generation system disturbances that involve real and reactive power swing through the main generator directly affect this circuit and increase the potential of its loss during these events.

As a result of these shortcomings, in its letter dated April .0, 1990, the staff recommended that EPRI consider adding a second reserve transformer to the one already called for in the Evolutionary Requirements Document to improve the connection of the offsite transmission system to the safety portion of the onsite distribution systems (third tier). Each transformer, which will be directly connected to a switching station (switchyard), could then be made the normal source of power to one safety division (one powering two divisions for the BWR) and the backup power source for the opposite division. The advantage of this configuration is that the safety buses always will be connected to an offsite power source with minimal intervening components (e.g., non-safety buses and breakers), requiring no actuation of active system components when changing modes, and that a loss of one offsite power source will affect only one safety division (two possible for the BWR plant design).

In its letter dated July 23, 1990, EPRI stated that it considers the arrangement adopted in the ALWR design criteria preferable because the expected frequency of loss of power at the terminals of the auxiliary transformers is low and the conditional availability of the reserve circuit is high. It is not likely that power will be lost at the terminals of the auxiliary transformers because these transformers can be fed from either the transmission system or the main generator. Although the staff agrees that this appears to be an advantage, this advantage could be eliminated or reversed by connection of the transmission system through the lesser reliable main step-up transformers; by the need for actuation of the main generator breaker on unit trip, by combined load-rejection and loss-of-power events, or by the direct effects of generation disturbances on the offsite circuit. Also, although the connection to the main generator makes available an additional power source to the safety loads, it is not clear how large a benefit that will be. Historically, continued operation of main generators following full-load rejection has not been successful, and the BWR requirements call for only a 40-percent load-rejection capability. This benefit, therefore, may be greater during operation at lower power levels.

The staff's recommended configuration of two reserve transformers could be jeopardized if one of the reserve transformers that is normally powering a safety division is connected to a separate switching station of lower voltage. As indicated in Section 3.1 of this report, the lower normal availability of a separate lower voltage switching station makes it suitable primarily as a standby offsite power source. The two-reserve-transformer configuration could be modified so that all the safety divisions would normally be powered from the one reserve transformer connected to the higher voltage switchyard. Backup would then be provided from the other reserve transformer connected to the lower voltage switching station. This, however, would eliminate the benefit of having only one safety division affected by the loss of a single offsite power source. In designs that use two switchyards of approximately equal voltage ratings and capacities or that have only one switchyard, the two-reserve-transformer configuration would gain additional worth.

In summary, the staff concludes that the reliability of the offsite power supplies to the safety buses and, in particular, the normal power supply to the safety buses will, to a large extent, be dependent on the individual reliabilities of its subsystems (e.g., main step-up transformer, generator circuit breaker, generator load-rejection capability, system control, and protection logics). The configuration specified in Section 3 of Chapter 11 is an improvement over past designs in which fast-transfer schemes on a generator trip are used and a significant improvement over past designs with a reliable main generator 100-percent load-rejection capability. Therefore, this configuration meets all regulatory requirements and is acceptable. However, the suggested two-reserve-transformer configuration would likely be a better choice in those designs that do not provide for high reliability of such subsystems as the main step-up transformer, generator circuit breakers, and generator load-rejection capability, especially when only one switchyard or separate switchyards of equal voltage and capacity are used in the design.

3.3 <u>Conclusion</u>

The staff concludes that the requirements in Section 3 of Chapter 11 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are acceptable.

4 MEDIUM-VOLTAGE AC DISTRIBUTION SYSTEM

4.1 Function and Description

Section 4.1 of Chapter 11 of the Evolutionary Requirements Document states that the medium-voltage ac distribution system will consist of the onsite electric power distribution circuits that operate at voltages ranging typically from 4.16 kV to 13.8 kV and supply power to medium-voltage safety, permanent non-safety, and non-safety loads. The system will include switchgear buses, circuit breakers, and unit substation transformers as well as their associated local instrumentation, controls, and protective relays. It also will include all buses and cables connecting the switchgear buses to their sources and loads.

Section 4.2.2 of Chapter 11 specifies that, in case of a loss of power from the unit auxiliary transformers, the safety and permanent non-safety loads will be automatically transferred to the reserve source of offsite power. In case of a loss of power from both the unit auxiliary transformers and the reserve transformer, the safety loads will be automatically transferred to standby safety power sources (diesel generators) and selected permanent non-safety loads will be automatically transferred to a standby non-safety power source (combustion turbine generator). The medium-voltage ac distribution system is also required to be designed to permit feeding the safety loads from the combustion turbine generator following a manual load transfer and, conversely, to permit feeding the permanent non-safety loads from the diesel generators following manual load transfer.

Two safety buses are specified in the PWR design criteria to power the safety loads, while three safety buses are specified in the BWR design criteria to power the safety loads. Two dedicated non-safety buses are specified in both design criteria for powering the permanent non-safety loads.

4.2 Evaluation

4.2.1 Lack of Alternate Power Source for Non-Safety Loads

One of the major differences between the distribution systems specified in Chapter 11 and those found in the most recently licensed nuclear plants is that no alternate power source is provided for the non-safety loads required for unit operation. Section 4.2.2 of Chapter 11 requires that only the safety and permanent non-safety loads have the capability to transfer to the reserve source of offsite power. The non-safety loads that will not have an alternate source of power include the reactor coolant pumps, reactor recirculation pumps, feedwater pumps, condensate pumps, and circulating water pumps. As a result, a loss of power to these loads that could be caused by a failure (fault) anywhere on the unit auxiliary transformer, main step-up transformers, or their connecting feeders would result in a plant trip and the loss of reactor coolant system forced circulation and normal feedwater systems. The same would occur for a 100-percent load rejection caused by the opening of the main generator high-side circuit breakers located in the switching station, if the generator load-rejection capability was unreliable (see the discussion in Section 3.2.2 of this report concerning staff concerns related to the main offsite power circuit that will feed the non-safety loads). Reliance, following the above events, therefore, must be placed on natural circulation and safety systems such as the auxiliary feedwater and reactor core isolation cooling systems. In most current designs, including those in which generator breakers are used (e.g., Millstone Unit 3, Summer, Catawba, and McGuire), two sources of power are provided to these non-safety loads so that they would only be lost if these events occurred simultaneously with a loss of offsite power.

In its letter dated July 23, 1990, EPRI stated that for the events considered by the staff, an additional source of power would not reduce the number of trips, nor would it greatly reduce the frequency of loss of power to the non-safety loads, since this frequency is dominated by the frequency of loss-of-offsite-power events. The staff disagrees that an additional source of power would not reduce the frequency of loss of power to the non-safety loads. If the majority of loss-of-offsite-power events were due to grid blackout and severe weather, an additional power source connected to the blacked-out switchyards would be of little use. However, the majority of the loss-of-offsite-power events have been plant-centered events. These events, which typically involve hardware failures, design deficiencies, human errors, localized weather-induced faults (lightning), or combinations of these failures, are more localized in nature and, therefore, less likely to result in the blackout of an entire switchyard or grid. An additional transformer connected to that switchyard and supplying non-safety loads should, therefore, significantly improve the frequency of loss of power to those loads.

The staff has not maintained that reducing the number of plant trips is a primary reason for recommending an additional power source for the non-safety loads. Rather, a primary reason for the additional power source is to reduce the subset of those plant trips that involve a loss of power to the non-safety loads. The combination loss-of-non-safety-power and subsequent turbine-trip event would likely be replaced with the turbine-trip-only event for the initiations (main step-up transformer fault, etc.) considered by the staff. The transients associated with a turbine-trip-only event have been identified as less severe than those associated with the loss-of-non-safety-power event analyzed in plant safety analysis reports and standard plant safety analysis reports.

EPRI also stated that the ALWR design is based on fundamental guiding principles, which include increased design margins intended to make the ALWR plant referencing the Evolutionary Requirements Document particularly robust. The core damage frequency will be less than $1xE^{-5}$ per reactor-year. The ALWR design will achieve significant improvements in plant safety (and availability) over current designs. The contribution of sequences initiated by a loss of offsite power will be minimized, and the incremental improvements that could be achieved by requiring a second source of power for the non-safety loads that only will be required for unit operation are considered very small and unwarranted. However, the staff does not agree that the improvements that could be achieved by installing a second source of power for non-safety loads are very small and unwarranted.

In its DSER for Chapter 11, the staff concluded that the second source would significantly reduce the number of plant trips that involve a loss of power to the non-safety loads and that the ALWR design criterion in this area was less conservative than that in existing plant designs and, therefore, was not acceptable. The staff recommended that an alternate power source for the non-safety loads should be required in Chapter 11, or EPRI should demonstrate that the design margins alluded to in its response of July 23, 1990, result in transients for a loss-of-non-safety-power event in an ALWR plant that are no more severe than those associated with the turbine-trip-only event in current existing plant designs. This was identified as a policy issue in SECY-91-078 and as an open issue in the DSER for Chapter 11.

It was the staff's intent that an alternate power source be provided to a sufficient string of non-safety loads so that forced circulation could be maintained and the operator would have the complement of non-safety equipment available to bring the plant to a stable shutdown condition, following a loss of the normal power supply and plant trip. To maintain forced circulation over the course of the transient and ease operator burden, an automatic transfer to the alternate power supply was an option that would have to be considered. EPRI has stated its reluctance to provide a fast automatic transfer scheme to the alternate supply because of the potential problems associated with that type of transfer. As a result, the staff agreed that a slow automatic transfer would be acceptable, although the coastdown capability (inertia) of the reactor coolant pumps would have to be relied on for the short duration of the transfer from the normal supply to the alternate supply. The staff also agreed that the full complement of reactor coolant pumps would not have to be powered provided there were no negative safety implications in doing so (e.g., reverse-flow concerns or stagnant flow).

In a letter dated February 4, 1992, EPRI revised the Evolutionary Requirements Document to include a requirement that the medium-voltage ac distribution system be designed to permit energizing the buses of the first tier (i.e., the non-safety loads) from the reserve power supply circuit (via the reserve transformer). The design will permit manual startup and operation of a large load connected to these buses (e.g., a reactor coolant pump or a condensate pump) in the event of a loss or unavailability of the normal supply. In the rationale provided with the requirement, EPRI originally stated that this capability was expected to be provided by a direct connection between the buses and the reserve transformer or by the removable links normally installed on the auxiliary transformers. When the links would be removed, power could be fed from the second-tier buses that have a direct connection to the reserve transformer.

The staff did not accept the second option that would allow use of the removable links normally installed on the auxiliary transformers. The staff believes that the added benefit of the alternate power supply would not be achieved if such access would require time-consuming operations such as removing links. Therefore, the staff requires that a direct connection to the alternate power be specified. In a letter dated March 30, 1992, EPRI provided a revision to Chapter 11 on this issue that removed the option in the rationale of using the removable links associated with the auxiliary transformers.

Although EPRI's latest proposed requirement still does not comply completely with the staff's intent, it does enhance EPRI's original design capability for responding to a loss-of-normal-power and plant-trip event. Therefore, EPRI's proposed requirement minimally satisfies the staff requirement for an alternate power source for the non-safety first-tier loads and is acceptable. The DSER open issue is closed.

The staff also notes, however, that the General Electric ABWR design provides for a reserve transformer that has the capability to power a sufficient complement of non-safety loads so that the plant can operate at full power with one unit auxiliary transformer out of service. Also, the Combustion Engineering System 80+ design has a startup feedwater pump connected to the second-tier buses that can be fed from either the main offsite power supply, the reserve offsite power supply, or the gas turbine-generator. It is, therefore, evident that the evolutionary plant designs, while complying with the new EPRI requirement, are proposing additional capabilities beyond EPRI's minimal requirement.

4.2.2 Connection of Safety Bus Offsite Power Sources Through Non-Safety Buses

Section 4.2.1 of Chapter 11 specifies that the medium-voltage ac distribution system will be designed to supply power to the safety loads from the normal power source (i.e., the unit auxiliary transformers). Section 4.2.2 of Chapter 11 specifies that in case of a loss of power from the unit auxiliary transformers, the safety loads will be automatically transferred to the reserve source of offsite power (i.e., the reserve transformer). Figures 11.2-1 and 11.2-2 of Chapter 11 show the safety loads normally powered from the unit auxiliary transformers through the permanent non-safety load buses (second tier). The unit auxiliary transformer winding that will feed these loads also will feed a portion of the non-safety loads (first tier). The safety and permanent non-safety load buses are also shown as being fed from common windings of the reserve transformer when the unit auxiliary transformer is unavailable.

In its letter dated April 10, 1990, the staff concluded that feeding the safety buses from the offsite power sources through non-safety buses, or from a common winding with non-safety loads, was not the most reliable configuration. It makes it more difficult to obtain good voltage regulation at the safety buses, it subjects the safety loads to transients caused by the non-safety loads, and it adds additional failure points between the offsite power sources and the safety loads.

In its letter dated July 23, 1990, EPRI stated that in many current designs in the United States and foreign plants, safety buses are fed through non-safety buses or from common transformer windings, and operating experience with these designs has not indicated any particular shortcomings. EPRI stated that there are real benefits in not connecting the safety buses directly to the offsite power supply, such as better protection of Class 1E systems against voltage surges affecting the offsite source and reduced risk of faulty paralleling of the onsite standby emergency sources with the offsite sources. EPRI also stated that the ALWR design criteria provide for a direct connection between safety buses and the reserve offsite source in the event of problems with the non-safety buses through which the safety buses are normally fed.

In the DSER for Chapter 11, the staff concluded that EPRI should clarify its assertion that the connection of safety buses through non-safety buses or from common transformer windings would reduce the risk of faulty paralleling of the onsite standby emergency sources with the offsite sources. In general, it has been the staff's experience that the benefits to safety of not connecting safety buses through non-safety buses or to common transformer windings usually outweigh whatever safety benefits may be achieved. IEEE 765-1983, "IEEE Standard for Preferred Power Supply for Nuclear Power Generating Stations," also states that the direct connection of the two offsite circuits to each redundant safety bus may further improve availability.

However, the staff also recognized that this design feature must be viewed in the context of the overall plant electrical system design and that some of the ALWR design concepts and objectives, such as the three-tier concept and the objective to simplify the design, bear on the choices made by EPRI. Therefore, the staff concluded that, as a minimum, at least one offsite circuit to each redundant safety division should be supplied directly from one of the offsite power sources with no intervening non-safety buses in such a manner that the offsite source can power the safety buses if any non-safety bus should fail. The transfer to this circuit should be automatic if the circuit is not normally connected to the safety buses and is one of the two normal paths of power from the main and reserve offsite power sources to the safety buses. The transfer to this circuit may be manual if the circuit is an additional third path of offsite power from the main or reserve offsite power sources for the safety buses. This issue was identified as an open issue in the DSER for Chapter 11.

In a letter dated November 26, 1991, EPRI revised the Evolutionary Requirements Document to require that at least one offsite circuit to each redundant safety division be supplied directly from one of the offsite power sources with no intervening non-safety buses in such a manner that the offsite source can power the safety buses if any non-safety bus should fail. Connection of a safety bus to its alternate power supply circuit will be accomplished manually using the source circuit breaker of the normal power supply circuit racked out from its normal switchgear position and inserted in an empty switchgear position associated with the alternate power supply circuit or using a source circuit breaker that is normally locked open and interlocked with the source circuit breaker of the normal power supply circuit. These additional requirements satisfy the staff's concern; therefore, this open issue is resolved.

4.2.3 Security

Section 4.1.3 of Chapter 11 specifies that the security systems will be one of the loads supplied via the medium-voltage power system. In its letter dated May 24, 1989, the staff concluded that the combustion turbine (CT) generator will need to be protected as vital equipment. In its September 15, 1989, response, EPRI stated that the CT generator and the equipment powered by it do not meet the definitions of vital equipment in 10 CFR 73.2 and in Section 5.2.1.1 of Chapter 9 of the Evolutionary Requirements Document.

In the DSER for Chapter 11, however, the staff noted that 10 CFR 73.55(e)(1) and (f)(4) and Generic Letter 87-08, "Implementation of 10 CFR 13.55 Miscellaneous Amendments and Search Requirements," specify that onsite secondary power supply systems for security equipment must be located in a vital area. The staff concluded that current regulations would require the CT generator, its electrical distribution switchgear, and its supporting fuel, cooling, starting, and control systems to be protected as vital equipment; that is, the equipment will have to be located in a locked and alarmed area within the protected area. The cabling between the CT generator and the vital equipment it supports also would need to be in a vital area if it is identifiable, such as would be the case if the CT generator were in a separate building and accessible without requiring heavy equipment to remove hatches. In the DSER, the staff identified this as an open issue.

In Revision 3, EPRI revised Section 5.2.12 of Chapter 9 to specify a separate, dedicated backup power source for the security systems located in a vital area, rather than the CT generator.

Since the CT generator is no longer specified for use as the onsite secondary power supply system for security equipment, and the separate, dedicated security backup power source will be located in a vital area, this DSER open issue is closed.

4.2.4 Use of Adjustable Speed Motor Drives

The Evolutionary Requirements Document requires that adjustable speed drives be used for some of the motors. For example, Section 5.3.4.1 of Chapter 3 requires that adjustable speed drives be used for the reactor internal pump motors in BWR designs, and Section 4.4.5.4.3 of Chapter 2 specifies that adjustable speed drives be used for the feedwater pump motors. Section 4.4.5.4.5 of Chapter 2 requires that the adjustable speed feedwater pump motors be the synchronous type with a load-commutated inverter solid-state power supply capable of providing the frequency, range, and power required by the pump motor in all specified modes of operation. Solid-state power supplies to heavy power loads generally create large amounts of harmonic distortion on the distribution systems that feed them. The distortion can cause problems for other equipment connected to the same distribution system. In its letter of January 10, 1992, EPRI stated that recent plant experience with large adjustable speed motor drives indicates that proper design can suppress harmonics to acceptably low levels. EPRI stated that large adjustable speed drive installations now typically include an input transformer ahead of the solid-state converter section that can limit harmonics to under 3-percent total voltage distortion. EPRI referenced IEEE 519 and Department of Defense DOD-STD-1399 as providing recommended limits of no more than 5-percent total harmonic voltage distortion and stated that a requirement will be included in Section 2.6.2 of Chapter 11 to limit the harmonic distortion caused by adjustable speed drives to a conservative value of maximum 3 percent.

EPRI's proposed requirement to limit the total voltage distortion to 3 percent should greatly reduce the amount of equipment that is affected by the harmonic distortion. If any remaining sensitive equipment is affected by this relatively low level of distortion, modification of the equipment itself would likely be more appropriate than further reduction of the distribution system voltage distortion. EPRI's new requirement is acceptable. The staff will ensure that these requirements are implemented in the evolutionary plant standard designs during its reviews of individual applications for FDA/DC.

4.2.5 Electrical Fault Effects on the Coastdown Capability of Reactor Coolant Pumps and Reactor Internal Pumps

Reactor coolant pump (RCP) systems in evolutionary PWR plants and reactor internal pump (RIP) systems in evolutionary BWR plants will be designed with a specified amount of coastdown capability to ensure that sufficient reactor coolant system flow will be maintained following loss of power to the pumps to ensure that departure-from-nucleate-boiling-ratio (DNBR) limits in PWRs and minimum-critical-power-ratio (MCPR) limits in BWRs will not be exceeded. In the PWR designs, the coastdown capability will be provided in the RCPs, and in the evolutionary BWR designs, the coast[illegible] capability will be provided in motor generator sets that will feed 6 [illegible] RIPs. The coastdown capability is typically most crucial in the first few seconds following the loss of power to the pumps when the excursion toward the DNBR and MCPR limits are the greatest.

In both the PWR and BWR designs, the RCPs and the RIP motor generator sets will be fed from unit auxiliary transformers that will be solidly connected (no intervening circuit breakers) to the main step-up transformers. The staff is concerned that a fault on that circuit may not be analyzed for its effect on the coastdown capability of the RCPs and RIPs. If a fault were to occur on that circuit during plant operation and the circuit breakers to the RCPs or RIP motor generators were not tripped immediately, the RCP motors and the RIP motor generator motors would briefly feed the fault, which would create a braking effect on those motors reducing their speed. In past designs this effect may not have been much of a problem because many of them used a fast transfer that sensed the fault and immediately opened the circuit breaker to the faulted normal power source and closed the circuit breaker to the alternate power source of the RCP buses. In the evolutionary plant designs, however, automatic transfers of the RCP or RIP buses will not be used (see Section 4.2.1 of this report). Therefore, during its review of an application for FDA/DC, therefore, the staff will ask the plant designers to analyze the effect on the coastdown capability of the RCPs and RIPs of electrical faults on the RCP and RIP motor generator power sources.

4.3 Conclusion

The staff concludes that the requirements in Section 4 of Chapter 11 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and are acceptable.

5 ONSITE STANDBY AC POWER SUPPLY SYSTEM

5.1 Function and Description

Section 5.1 of Chapter 11 of the Evolutionary Requirements Document states that the onsite standby ac power supply system will include the onsite standby safety and non-safety ac power sources and their associated power supply circuits up to the source breakers of the onsite ac distribution systems. The standby power sources will consist of the prime movers and ac generators, their auxiliary systems, the fuel storage and transfer system, and the associated local instrumentation and control systems. The term "standby power source" as used in the Evolutionary Requirements Document refers to both safety and non-safety sources. EPRI states that Chapter 11 distinguishes between the safety and non-safety standby power sources where necessary.

Section 5.2 of Chapter 11 states that the onsite safety standby power sources will be emergency diesel generators (EDGs) and the onsite non-safety power source will be a combustion turbine (CT) generator. Section 5.4 of Chapter 11 specifies that two identical, functionally redundant, and electrically independent diesel generators will be supplied in the PWR design - one dedicated to each of the two independent safety divisions. Three identical, functionally redundant, and electrically independent diesel generators are required for the BWR design - one dedicated to each of the three independent safety divisions. Only one CT generator is required in both the PWR and BWR designs and will have the capability to feed either or both permanent non-safety load buses.

Section 5.3.1 of Chapter 11 states that the diesel generators will be required to have sufficient capacity to operate the engineered safety features needed to maintain the plant in a safe condition in the event of a loss-of-coolant accident concurrent with a loss of offsite power. The CT generator is required to be capable of coping with a station blackout, of feeding permanent non-safety loads during loss-of-offsite-power events, and of backing up the diesel generators in case they fail or are unavailable.

5.2 Evaluation

5.2.1 Use of the Combustion Turbine Generators To Satisfy Technical Specification Requirements

Section 5.1.2 of Chapter 11 states that when the plant is in cold-shutdown conditions, the non-safety portion of the onsite standby ac power supply system also can be used to supply plant power during maintenance of the offsite power supply system. In its letter dated April 10, 1990, the staff informed EPRI that although the onsite standby ac power supply system may have the literal capability to comply with EPRI requirements, the staff has made no judgment at this stage of its review as to what extent, if any, the CT generator could be used as an alternate power source to satisfy technical specification requirements for the purpose of performing maintenance on the offsite power supply system during shutdown.

By letter dated July 23, 1990, EPRI responded that it is expected that the CT generator will be capable of performing the safety function specified for an alternate power source during plant shutdown. Therefore, EPRI concluded that the use of the CT generator as an alternate power source under such conditions should satisfy technical specification requirements for the purpose of performing maintenance on the offsite supply system.

During its review of the ALWR evolutionary plant technical specifications of an individual application for FDA/DC, the staff will evaluate the use of the CT turbine generator to satisfy technical specification requirements.

5.2.2 Use of the Combustion Turbine Generator To Meet Station Blackout Coping Requirements

Although Section 5.2.4 of Chapter 11 specifies that the CT generator will be capable of coping with a station blackout, in its rationale. EPRI originally stated that the ability to qualify this onsite backup power supply as an alternate ac (AAC) power source will provide the plant owner with two options to comply with station blackout regulations: (1) coping by means of an AAC power source or (2) coping by means of battery and system capacities already specified in Section 2.3.3 of Chapter 5 of the Evolutionary Requirements Document.

EPRI's rationale indicated that the ALWR plant owner will be able to select either the CT generator or the battery and system capacities as the means that will be used at the plant to comply with the NRC station blackout regulatory requirements. The staff recognizes and endorses the much improved safety benefit that the combination of these two features provides to the ALWR plant; however, it has taken the position (SECY-90-016) that an AAC power source should be the primary means used in evolutionary ALWR plants to meet NRC station blackout regulatory requirements.

In the DSER for Chapter 11, the staff concluded that the Evolutionary Requirements Document should be revised to clearly indicate that the CT generator will be qualified as an AAC power source by the ALWR plant owner and that it will be the means to comply with NRC station blackout regulatory requirements. This will ensure that any future regulatory requirements on AAC power sources, such as surveillance of or limitation on allowed outage times necessary to maintain required levels of availability and reliability, will be applied to the CT generators in evolutionary ALWR plants. This was identified as an open issue in the DSER.

In a letter date February 3, 1992, EPRI revised the Evolutionary Requirements Document to indicate that the ALWR plant owner will qualify the CT generator as an AAC source and that it will be the means to comply with station blackout requirements. This satisfies the staff's concern; therefore, this open issue is resolved.

5.2.3 Power Rating of the Combustion Turbine Generators

Section 5.3.1.4 of Chapter 11 of the Requirements Document specifies that the CT generator will have a short-term power rating greater than the sum of the permanent non-safety loads and safety loads that must be powered by the unit at any one time. It further specifies that the unit will be sized for load starting and steady-state operation on the basis of the more limiting of the following loading conditions:

- The unit supplies power to both divisions of permanent non-safety loads (intended normal operating condition).

- The unit supplies power to one safety division and one division of permanent non-safety loads (intended operating condition in case a diesel generator is unavailable).

Although the above requirements specify the loading that the CT generator is to supply in terms of the divisions it must be able to supply, it is not clear during what scenarios and, therefore, what complement of loads it must supply within those divisions. In its letter dated April 10, 1990, the staff recommended that the CT generator be specified to power, as a minimum, the worst-case shutdown (to cold shutdown) or accident loads (whichever is greater) within the above-specified complement of divisions. In addition, the staff recommended that the CT generator have the capability to power those loads with some margin for load growth, when operating within its continuous rating.

By letter dated July 23, 1990, EPRI agreed to require that the CT generators be capable of powering the worst-case shutdown or loss-of-coolant-accident (LOCA) loads as recommended by the staff; but the unit was only required to have that capability when operating within its short-term power rating, rather than within its continuous rating as recommended by the staff. EPRI stated that it did not consider it justified to require that the CT generator be sized for continuous operation at maximum loading, including all initial design margins, given that operation of the unit under the specified conditions would not last more than a few hours.

The staff agrees with this rationale for operation during LOCA events, since the capability of the CT generator to power LOCA loads during these scenarios is provided only as a backup to the diesel generator power sources. For station blackout purposes, however, the CT generator should be the primary means of coping with a station blackout and bringing the plant to a cold-shutdown condition in an evolutionary ALWR design.

In the DSER for Chapter 11, the staff concluded that, as a minimum, the CT generator should be capable of powering one safety division and one division of permanent non-safety loads during the worst-case shutdown (to cold shutdown) and that it should have the capability to power these loads with some margin for load growth when operating within its continuous rating. This was identified as an open issue in the DSER.

In a letter dated November 26, 1991, EPRI reiterated its position to use a 2000-hour rating (overload rating) of the CT unit to accommodate one safety division and one division of permanent non-safety loads for the worst-case shutdown or LOCA event. The staff concludes that to use the overload rating of the CT unit for evolutionary plant designs, at this stage of the design when accurate determination of the required load is not known, is not justified. Therefore, the staff maintains that the CT unit should be sized to power these loads, with some margin for load growth when operating within it continuous rating. The staff also notes that proposed Regulatory Guide 1.9, "Selection, Design, and Qualification of Diesel-Generator Units Used as Standby (Onsite) Electric Power Systems in Nuclear Power Plants," Revision 3, recommends that the EDGs be sized on the basis of their continuous rating rather than their short-term (overload) rating. The staff will pursue this issue with the plant designers during its reviews of individual applications for FDA/DC. Therefore, this DSER open issue is closed.

5.2.4 Power Rating of the Diesel Generators

Section 5.3.1.1 of Chapter 11 specifies that each diesel generator unit will be capable of supplying the electric power required to operate the engineered safety features needed to maintain the plant in a safe condition in the event of a LOCA concurrent with a loss of offsite power. Section 5.3.1.2 of Chapter 11 specifies that the continuous power rating of each diesel generator unit will be determined on the basis of its worst-case load starting and steady-state operation when supplying power to the safety systems of its corresponding safety division. Specifically, it will be greater than the sum of all safety loads that must be powered by that unit at any time.

Neither of the above sizing requirements include provisions for powering permanent non-safety loads, although Sections 4.2.6 and 5.3.3.4 of Chapter 11 state that it is intended that the diesel generators have the capability to feed selected permanent non-safety loads in the event of a loss of all sources of power to those loads. Therefore, in its letter dated April 10, 1990, the staff informed EPRI that the sizing criteria also should specify that each diesel generator will be sized to power some portion of the permanent non-safety loads and that the pressurizer heaters (that portion required by Three Mile Island Action Plan (TMI) Item II.E.3.1) should be included in the group of permanent non-safety loads that the diesel generators will be sized to handle.

In its letter of July 23, 1990, EPRI stated that the worst-case loading of safety loads is expected to occur under LOCA conditions, and no non-safety loads will be connected to the diesel generator under such conditions. Loading of some non-safety loads such as the pressurizer heater will only occur under non-LOCA conditions in the low-probability event of a loss of the normal and reserve offsite power supplies followed by a failure of the CT. Under those circumstances the expected load on the diesel generators, including those non-safety loads, is not expected to exceed the short-time rating of units sized in accordance with Section 5.3.1.2 of Chapter 11. EPRI indicated that the diesel generator would be sized to comply with Regulatory Guide 1.9, under all design conditions.

In the DSER for Chapter 11, the staff concluded that the diesel generators should not be sized for only the LOCA condition and that their capability to supply a portion of the permanent non-safety loads should be defined in the Evolutionary Requirements Document, particularly when at least a portion of those loads (e.g., pressurizer heaters and lighting) has some safety significance. The staff also concluded that EPRI should specify that the continuous power rating of the diesel generators be sufficient to supply some portion of the pressurizer heaters (as required by TMI Item II.E.3.1) and lighting. This was identified as an open issue in the DSER.

In a letter dated January 24, 1992, EPRI disagreed with the staff that non-safety loads (pressurizer heaters and emergency lighting) should be part of the basis for the diesel generator continuous power rating. The staff concludes that in order to meet TMI Item II.E.3.1, those minimum number of pressurize heaters required to maintain natural circulation conditions in the event of loss of offsite power must be powered from redundant diesel generators. Therefore, the staff will review individual applications for FDA/DC to ensure that vendors perform a power analysis to determine which load(s) must be disconnected from the safety buses to accommodate pressurizer heaters when required. Therefore, this aspect of the DSER open issue is closed.

Regarding emergency lighting, the staff concludes that in order to satisfy the requirements of SRP Section 9.5.3, "Lighting Systems," emergency lighting must be powered from the safety buses and that this load should be part of the basis for the diesel generator continuous rating. The staff also notes that all plants that received their operating license after TMI have powered the minimum number of pressurizer heaters required for natural circulation from the redundant safety buses. Also, the emergency lighting in these plants is powered from safety buses and is part of the diesel generator loading. The staff will pursue this issue with the plant designers during its reviews of individual applications for FDA/DC. Therefore, the remaining aspect of this DSER open issue is closed.

Section 5.3.1.2 of Chapter 11 also specifies the amount of load-carrying margin to be included in the sizing of the diesel generators. It states that sufficient margin will be provided in the size of the diesel generators to accommodate the load growth expected to occur over the life of the plant. It further states that this margin, however, will be kept to a minimum, not to exceed 10 to 15 percent.

In its letter of April 10, 1990, the staff stated its concern regarding the small amount of margin specified by EPRI considering the proposed 60-year design life of an ALWR plant, the specified capability of the diesel generator to feed a portion of the permanent non-safety loads, and the experience with load creep in older plants. The staff recommended that consideration be given to specifying a margin requirement of at least 20 percent and that it be made clear that the full amount of this margin be included within the continuous rating of the diesel generator rather than the short-time power rating.

By letter dated July 23, 1990, EPRI stated that system expansion and load growth should not occur with a standardized certified plant design that is based on mature technology. Therefore, no expansion of essential systems and no growth among loads that are important enough to be powered by the diesel generators are expected. Nevertheless, EPRI believes it prudent to require some minimum margin and estimates that 10 or 15 percent is all that should be needed. EPRI agreed that this margin should not be included in the short-time rating of the diesel generators and would modify Chapter 11 accordingly.

In the DSER for Chapter 11, the staff concluded that EPRI had agreed to provide the full amount of the margin in the continuous rating of the diesel generators and that this was acceptable, provided EPRI revised the Evolutionary Requirements Document to include this requirement. This was identified as a confirmatory issue in the DSER. In a letter dated November 26, 1991, EPRI revised the Evolutionary Requirements Document to specify a margin of 10 to 15 percent in the continuous rating of the diesel generator. The staff has confirmed that EPRI has met its commitment, and the confirmatory issue is closed.

5.2.5 Emergency Diesel Generator LOCA/LOOP Sequences

Section 5.3.3.3 of Chapter 11 originally stated that following a loss of offsite power (LOOP), either without a LOCA or concurrent with a LOCA, each diesel generator unit would automatically start, accelerate to rated speed, reach nominal voltage, and supply power to required safety loads. In its letter dated April 10, 1990, the staff requested that EPRI specify that each diesel generator unit will automatically start (if it is not already running) and load the required safety loads whenever a LOOP occurs, either preceded by or followed by a LOCA. The staff indicated that the most likely LOCA/LOOP sequences would probably not occur at precisely the same time, so this provision was necessary to ensure that the diesel generators respond properly regardless of the sequence.

By letter dated July 23, 1990, EPRI stated that the requirement as currently written had the same meaning as the staff's comment, and that there was no requirement regarding the sequencing of LOCA and LOOP events. To ensure there was no misunderstanding, however, EPRI indicated the requirement would be revised to read as follows:

> Following a loss of offsite power (LOOP), each EDG unit shall (if not already running) automatically start, accelerate to rated speed, reach nominal voltage, and be ready to supply power to the required safety loads.

In the DSER for Chapter 11, the staff concluded that the above revision did not address its concern that the Evolutionary Requirements Document did not require that the load-sequencing design for the ALWR provide for the capability of responding to a LOCA and LOOP in whatever order a combined LOCA and LOOP might occur. For instance, one of the more likely combined LOCA/LOOP sequences is a LOCA followed by a delayed LOOP. The scenario is that the LOCA occurs, resulting in a plant trip and load sequencing of the LOCA-mitigating loads onto the offsite power source. The loss of generating capacity to the offsite grid caused by the plant trip, however, results in grid instability or depressed voltage and eventual loss of offsite power some seconds later. This loss of offsite power occurs while the LOCA-mitigating loads are being loaded sequentially onto the offsite power source. The load-sequencing logic must now call for the LOCA-mitigating loads to be resequenced onto the diesel generators.

A requirement to design for such a scenario is necessary because some plant designs do not in fact have the capability to respond to such an event. They are only designed to respond to a combined LOCA and LOOP when they occur simultaneously. Although the simultaneous occurrence of a LOCA and LOOP is analyzed as a bounding event in order to determine the limiting response times of the safety equipment for the event, it is unlikely the LOCA and LOOP would occur at precisely the same time. The loading logic must therefore be designed to respond to the LOCA and LOOP in whatever order they might occur (LOOP only, LOCA only, LOCA followed by delayed LOOP, LOOP followed by delayed LOCA, or simultaneous LOCA and LOOP).

Section 4.5.5 of Chapter 11 partially addresses this issue by requiring that the load shedding and sequential loading schemes be automatically reset to perform as intended in the event the source breaker of the alternate power source trips during or after loading and the loads are to be reapplied. It would not, however, necessarily require that the LOCA loads be resequenced on the diesel generators for the LOCA/delayed LOOP event discussed above, nor would it require that LOCA loads be applied in the LOOP/delayed LOCA event, since the initiation of the LOCA does not necessarily result in a trip of the diesel generator source breaker. It also does not require automatic reset for a loss of an alternate power source that occurs for reasons other than a trip of the source breaker.

In the DSER for Chapter 11, the staff concluded that the Evolutionary Requirements Document should specifically require that the loading logic be designed to respond to a LOCA and LOOP in whatever order they might occur and identified this as an open issue.

In a letter dated March 3, 1992, EPRI revised the Evolutionary Requirements Document to include a requirement for the load shedding and sequencing logic provided for the diesel generator. The requirement is intended to ensure proper sequencing of the LOCA loads on the diesel generators in the event a LOOP occurs at any time after a LOCA or in the event a LOCA occurs at any time after a LOOP. This satisfies the staff's concern, and this open issue is closed.

On a related issue, the staff recommends that the Evolutionary Requirements Document contain a requirement that the emergency diesel generators have the capability to independently power the safety buses (with the plant at power and offsite power disconnected from the buses) while still retaining the capability to automatically respond to LOCA or LOOP events by automatically sequencing on the appropriate loads. This feature would allow the diesel generators to power the safety buses in a "protected bus" configuration following a manual operator transfer when the offsite system is in a situation that might jeopardize its availability or adequacy. Capability of the diesel generators to operate for extended periods powering only the normally operating safety bus loads (potentially light loading) also would have to be specified as part of this requirement. Most existing plants have the capability to independently power the safety buses; but not all retain the capability to respond to LOCAs or LOOPs in this configuration or have the capability to operate for extended periods under the potentially light loading of the normally operating safety bus loads. The staff will also make this recommendation during its review of an individual application for FDA/DC.

5.2.6 Emergency Diesel Engine Auxiliary Support Systems

Each EDG will have the following auxiliary systems:

- starting system
- combustion air intake and exhaust system
- cooling water system
- lubrication system
- fuel oil storage and transfer system

The design criteria proposed by EPRI for these systems are discussed below. The staff has evaluated these systems against the guidelines in the following sections of the SRP: Section 9.5.4, "Emergency Diesel Engine Fuel Oil Storage"; Section 9.5.5, "Emergency Diesel Engine Cooling Water System";

Section 9.5.6, "Emergency Diesel Engine Starting System"; Section 9.5.7, "Emergency Diesel Engine Lubrication System"; and Section 9.5.8, "Emergency Diesel Engine Combustion Air Intake and Exhaust System."

Emergency Diesel Engine Starting System

The design function of the emergency diesel engine starting system is to provide a reliable method for starting the emergency diesel engines for all modes of operation.

In Section 5.5.2 of Chapter 11, EPRI establishes the following key requirements for the starting system:

- Each EDG will be provided with two dedicated, redundant air starting systems.

- Each air starting system will be sized for five consecutive starts without recharging.

- To avoid corrosion or scaling problems, each air starting system will be provided with air dryers and air filters, and the piping material will be stainless steel or copper.

- The EDG units, including all auxiliary systems, will be classified as Class 1E and seismic Category I equipment.

In its response of December 22, 1989, to a staff's request for additional information dated September 14, 1989, EPRI stated that the detailed design of the system, which will vary somewhat between system designers and according to the equipment manufacturer, had not been defined and was not intended to be covered by the Evolutionary Requirements Document.

The staff concludes that the requirements established for the emergency diesel engine starting system do not conflict with SRP Section 9.5.6 and are acceptable. However, the staff will evaluate details of this system during its review of an individual application for FDA/DC.

Emergency Diesel Engine Combustion Air Intake and Exhaust System

The basic function of the emergency diesel engine combustion air intake and exhaust system is to supply combustion air of suitable quality to the diesel engines and to exhaust the combustion products from the diesel engine to the atmosphere.

In Section 5.5.3 of Chapter 11, EPRI establishes the following key requirements for the combustion air intake and exhaust system:

- Each EDG will be provided with an independent combustion air intake and exhaust system. The system will be sized and physically arranged so that no degradation of engine function will be experienced when the unit is required to operate continuously at its maximum rated power output.

- Each combustion air intake system will be provided with means of reducing airborne particulate material entering the system, assuming the maximum expected airborne particulate concentration at the combustion air intake.

- The arrangement and location of the combustion air intake and exhaust structures will be such as to preclude a reduction of engine power output due to intake of exhaust gases or other diluents (e.g., fire suppression agents) that could reduce oxygen content below acceptable levels.

- The components of the combustion air intake and exhaust system that are exposed to atmospheric conditions will be protected from possible clogging as a result of ice, snow, dust, etc.

The staff concludes that the requirements established for the emergency diesel engine combustion air intake and exhaust system do not conflict with SRP Section 9.5.8 and are acceptable.

Emergency Diesel Engine Cooling Water System

The design function of the emergency diesel engine cooling water system is to maintain the temperature of its associated diesel engine within a safe operating range under all load conditions and to keep the engine coolant preheated during standby conditions to improve starting reliability.

In Section 5.5.5 of Chapter 11, EPRI establishes the following key requirements for the cooling system:

- Each EDG will have its own independent cooling system, which will include a primary engine and turbocharger cooling loop.

- The cooling system will be a closed-cycle system and will serve as an intermediate system between the diesel engine and the component cooling water system of the same division as the particular EDG.

- Each EDG will be equipped with a set of engine-driven cooling water pumps designed to meet the full-load requirements for water circulation through the primary engine and turbocharger cooling loops.

- Water circulation through the cooling system of the EDG for prewarming purposes will be by natural convection of the heated water.

- The prewarming system will be sized to maintain water temperature above 120 °F and oil temperature above 80 °F.

The staff concludes that the design requirements established for the emergency diesel engine cooling water system do not conflict with SRP Section 9.5.5 and are acceptable.

Emergency Diesel Engine Lubrication System

The basic function of the emergency diesel engine lubrication system, which is an integral part of the diesel engine, is to provide essential lubrication and cooling for the components of the diesel engines.

In Section 5.5.6 of Chapter 11, EPRI establishes the following key requirements for the lubrication system:

- Each EDG will have its own independent lubrication system and be equipped with a set of engine-driven pumps.

- Each EDG will be provided with a pre/post-lubrication system consisting of an ac motor-driven pump and a backup dc motor-driven pump designed to ensure continuous prelubrication while the EDG is in the standby mode. Transfer from the normal ac motor-driven pump to the backup dc pump will be automatic in case of pump failure or loss of ac power.

The staff concludes that the requirements established for the emergency diesel engine lubrication system do not conflict with SRP Section 9.5.7 and are acceptable.

Emergency Diesel Engine Fuel Oil Storage and Transfer System

The basic function of the emergency diesel engine fuel oil storage and transfer system is to provide a separate and independent fuel oil supply train for each diesel generator and to permit operation of the diesel generator at full load for a minimum of 7 days without replenishing fuel.

In Section 5.5.10 of Chapter 11, EPRI establishes the following key requirements for the emergency diesel engine fuel system:

- Each EDG will be provided with an independent fuel supply system in order to prevent a single failure from affecting more than one unit.

- Each fuel supply system will be provided with fuel filters and water separators in the supply lines to ensure fuel quality.

- Each fuel oil storage tank will be sized to support operation of the associated EDG at its maximum continuous rating for a minimum of 7 days.

- Each day tank will have enough capacity to operate its associated EDG for at least 4 hours at its maximum rated capacity.

- Each fuel oil tank will have the capacity to be tested for the presence of water and, if necessary, to be drained of water from the tank bottom.

- Adequate access will be provided for sampling fuel oil throughout the fuel supply system.

In its response of December 22, 1989, to a staff's request for additional information dated September 14, 1989, EPRI stated that the Evolutionary Requirements Document does not define the detailed design features and administrative controls required to maintain the quality of the stored fuel oil, to protect the supply lines from contamination, or to minimize fire hazard during and after filling operations. The plant designer is expected to define these detailed design features and administrative procedures in consultation with the plant owner and operator on the basis of the particular arrangement of the fuel oil storage and transfer system. In addition, the design of the filters and the location of the transfer pumps have not been defined. The final system design will ensure that the pumps will have sufficient head and capacity to transfer fuel oil to the day tanks as required.

The staff concludes that the design requirements established for the emergency diesel engine fuel oil storage and transfer system do not conflict with SRP Section 9.5.4 and are acceptable. However, the staff will evaluate details of the system during its review or an individual application for FDA/DC.

Conclusion

The staff concludes that the requirements in Section 5.5 of Chapter 11 of the Evolutionary Requirements Document do not conflict with SRP Sections 9.5.4, 9.5.5, 9.5.6, 9.5.7, or 9.5.8 regarding emergency diesel engine auxiliary systems and are acceptable.

5.2.7 Safeguards Consideration

As discussed in Section 5.2.2 of this report, Section 5.2.4 of Chapter 11 specifies that the combustion turbine (CT) will be able to back up the safety EDG units to provide an additional means of coping with a station blackout. Section 5.5.5.5 of Chapter 11 requires an air cooling system for the CT unit.

Chapter 6 of the Evolutionary Requirements Document requires the CT to be near the normal switchgear building and shows it within the plant protected area. The staff concludes that, in addition to the safety benefits derived from redundancy and diversity, these requirements will enhance the inherent resistance of the evolutionary ALWR plant to sabotage by preventing the sabotage of difficult-to-protect equipment, such as transmission lines, switchyards, and service water system sources that may be outside or on the periphery of the plant protected area, from causing the loss of all plant ac power. Therefore, these requirements are acceptable.

5.3 Conclusion

The staff concludes that the requirements in Section 5 of Chapter 11 of the Evolutionary Requirements Document for the onsite standby ac power supply system do not conflict with current regulatory requirements or guidance and are acceptable.

6 LOW-VOLTAGE AC DISTRIBUTION SYSTEM

6.1 Function and Description

Section 6.1 of Chapter 11 of the Evolutionary Requirements Document states that the low-voltage ac distribution system will consist of the onsite electric power distribution circuits that will supply power to the safety, permanent non-safety, and non-safety loads at 600 V or less. EPRI states that the system will not include the low-voltage vital ac power supply system or the normal and emergency lighting systems. These are covered in Sections 7 and 8 of Chapter 11. The system will include safety and non-safety load centers, motor control centers (MCCs), distribution transformers, and distribution panels as well as the associated protective relaying and local instrumentation and controls. Also included will be the cables, connections, and electrical penetrations used throughout the system.

Section 6.2.2 of Chapter 11 specifies that the low-voltage ac power distribution system will be designed so that the failure or unavailability of a single unit substation or distribution transformer will not preclude continuous system operation. Section 6.3.2 of Chapter 11 states that the load centers and MCCs are required to be of a double-ended design for the safety portions of the low-voltage ac systems in PWR plants; that is, provisions will be made to allow power to be supplied to these load centers and MCCs via separate circuits. EPRI states that redundant power supply circuits to safety load centers and MCCs are not required for BWR plants because that design specifies three safety divisions, provided continuous plant operation at 100-percent power with one Class 1E load center or MCC out of service is permitted for at least 96 hours. For the non-safety portions of the low-voltage ac distribution system, EPRI states that load centers will generally be double ended with provisions to receive power from both feeders and MCCs fed directly from a load center without an intermediate transformer generally will be single fed.

6.2 Evaluation and Conclusion

Although EPRI's statement that redundant power supply circuits to safety load centers and MCCs are not required for a BWR design with three safety divisions does not conflict with current regulatory requirements, EPRI stated that this design criterion was acceptable to the industry only if continuous plant operation at 100-percent power is allowed for at least 96 hours following the loss of one Class 1E MCC load center. The 96 hours specified by EPRI in Section 6.3.2 of Chapter 11 likely refers to an allowed outage time in the technical specifications for a BWR ALWR evolutionary plant. This is significantly greater than the specified allowed outage time for loss of a load center of 8 hours in the current Standard Technical Specifications.

During its review of the ALWR evolutionary plant technical specifications of an individual application for FDA/DC, the staff will evaluate the acceptability of a 96-hour allowed outage time for a load center in a BWR ALWR evolutionary plant.

The staff concludes, with the exception noted above, that the requirements in Section 6 of Chapter 11 of the Evolutionary Requirements Document do not conflict with current regulatory requirements or guidance and are acceptable.

7 DC AND LOW-VOLTAGE VITAL AC POWER SUPPLY SYSTEMS

7.1 Functions and Key Design Requirements

Section 7.1 of Chapter 11 of the Evolutionary Requirements Document states that the dc power supply system will consist of the electric power supply and distribution equipment and circuits that will provide dc power to the plant dc loads. The system will begin at the source terminals of the plant safety and non-safety battery chargers. It will end at the input terminals of the plant dc loads and at the input terminals of the inverters of the low-voltage vital ac power supply system. The low-voltage vital ac power supply system will consist of the electric power supply and distribution equipment and circuits that will provide low-voltage ac power for continuous operation of safety instrument loads, computer systems, and other important plant loads. The system will begin at the input terminals of the inverters and backup regulating transformers and end at the input terminals of the system's loads.

The system will include battery sets, battery chargers, inverters, regulating step-down transformers, motor control centers, distribution panels, associated protective relays and instrumentation, and all cabling and wiring from the source terminals up to the terminals of the system loads.

The following major provisions are specified in Section 7 of Chapter 11 for the dc and low-voltage ac power supply systems:

- The dc power supply system is required to be designed with sufficient redundancy to ensure that, in the case of loss of offsite power, the loss of any battery or dc bus concurrent with a single independent failure in any other system required for shutdown cooling will not result in a total loss of reactor cooling capability.

- The dc and low-voltage vital ac power supply systems are required to be designed with sufficient redundancy to ensure the following:

  - The failure or unavailability of a single battery, battery charger, or inverter will not result in a plant trip or a forced outage.

  - Each battery, battery charger, or inverter may be separately tested and maintained (including battery discharge tests, battery cell replacement, and battery charger and inverter replacement), and battery equalization may be performed off line with the plant at 100-percent power and without affecting plant operation.

- The batteries of the dc power supply system are required to be sized to meet the following operational requirements:

  - to supply power to their loads for a period of at least 2 hours on the basis of the most limiting load profile without load shedding

  - to permit operation of the station blackout coping systems for 8 hours, assuming manual load shedding and load management programs

- In the PWR plant, each dc bus is required to be connected to a battery and a battery charger. In addition, provision must be made to connect each bus to a standby, backup dc source (i.e., a combination of a battery and a battery charger). This backup source is required to have sufficient capacity to permit normal system operation in case of failure or unavailability of a single battery or battery charger.

- In the BWR plant, a configuration for the dc bus similar to that indicated above for the PWR plant is required to be used. However, because of the BWR plant's triple redundancy of safety divisions for most accident scenarios, backup dc sources for the Class 1E dc buses are not required, provided continuous plant operation at 100-percent power with any one Class 1E battery or battery charger out of service is permitted for at least 72 hours.

- Uninterruptible power supplies are required to be provided for operation of low-voltage vital ac safety loads, including reactor protection and safety systems actuation channels and safety systems instrumentation and control loads.

- Each uninterruptible power supply is required to be fed normally from a dc bus so as to eliminate the need for dedicated ac sources and rectifiers.

- Each uninterruptible power supply must be provided with a backup ac source, consisting typically of a regulating transformer, with sufficient capacity to allow normal system operation in case of failure or unavailability of a single inverter.

- Each uninterruptible power supply must be provided with make-before-break static switches for automatic transfer of the loads to the backup source of ac power on failure of the inverter. Manual switches must be provided for manual transfer to the backup power source for maintenance of the inverter or the static switch.

- Four separate and independent Class 1E dc and low-voltage vital ac uninterruptible power supplies are required to be dedicated to powering the four channels of the reactor protection system. Each dc source will include a battery and a battery charger capable of supplying power to its associated reactor protection system channel for a minimum of 2 hours.

- The non-safety portions of the dc and low-voltage vital ac power supply systems will be considered part of the permanent non-safety systems. As such, they must be energized from an ac source as long as power from an offsite power source or the onsite standby non-safety source is available.

- A separate 250-V dc non-safety dc power supply system must be provided for operation of the plant's large dc loads such as standby lube oil pumps or seal oil pumps.

- The non-safety 125-V dc power supply system will include redundant power supply buses, batteries, and battery chargers. Redundant chargers must be fed from separate ac buses.

* Uninterruptible power supplies must be provided for operation of non-safety low-voltage vital ac systems, including plant computers, instrumentation and control loads, security lighting, and fire detection systems.

7.2 Evaluation

7.2.1 Loss of Power to a DC Bus

Section 7.2.2 of Chapter 11 specifies that the dc and low-voltage vital ac power supply systems will be designed with sufficient redundancy to ensure that the failure or unavailability of a single battery, battery charger, or inverter will not result in a plant trip or a forced outage. In its letter dated April 10, 1990, the staff indicated that this requirement also should apply to the loss of a dc bus. That is, the loss of a dc bus should not result in a plant trip or a forced outage.

In its letter dated July 23, 1990, EPRI stated that the loss of power to a dc bus is usually the result of the failure or unavailability of the batteries or battery chargers supplying power to the bus rather than of a fault on the bus itself. EPRI indicated that this is particularly true if the dc system is operated ungrounded as required in the ALWR design criteria, and, therefore, it does not consider that establishing the same redundancy requirements for the dc buses as for the batteries and battery chargers is justified.

The staff's recommendation that the loss of a dc bus should not result in a plant trip or forced outage did not specifically identify the failure mechanism causing the bus loss (e.g., bus fault, failure of battery and charger, source breaker, or fuse) because, assuming no other system anomalies such as voltage surges, harmonics, or switching transients occur as a result of the failure, the effect on the loads is the same, that is, loss of power.

The staff i[illegible] oncerned about the wording of this requirement because the loss of a battery or of a charger does not necessarily result in a loss of power to the dc bus they supply. Therefore, a plant designer could conclude that the requirement specified in Section 7.2.2 of Chapter 11 is met by the installation of a charger qualified as a battery eliminator that can supply the bus when the battery is lost and a battery that can supply the bus when the charger is lost. However, the more specific requirements contained in Sections 7.3.2.2, 7.3.2.3, and 7.3.2.4 of Chapter 11 that call for four dedicated and independent sources of power to the four reactor protection system channels appear to result in a design that would meet the intent of a failed dc bus not resulting in a plant trip.

The basis for the staff recommendation is related to that addressed in Generic Safety Issue (GSI) A-30, "Adequacy of Safety-Related DC Power Supplies," which has been integrated into GSI 128, "Electrical Power Reliability." The concern is that a failure of a dc bus could cause a transient or plant trip requiring the response of safety systems, but those responses could fail because of a subsequent failure of an additional dc bus. GSI 128 is addressed in detail in Appendix B to Chapter 1 of the Evolutionary Requirements Document, which indicates that the ALWR design for the dc electrical power system will avoid the problems described in the generic safety issue. This issue is discussed by the staff in Appendix B to Chapter 1 of this report.

In the DSER for Chapter 11, the staff concluded that possibly not all losses of dc buses had been addressed. In addition, the requirements did not address the possibility that loss of a safety-related ac bus (low voltage or medium voltage) could result in a transient or plant trip. Therefore, the requirements of the Evolutionary Requirements Document were insufficient to ensure that loss of an electrical bus (either ac or dc) will not result in a plant transient and simultaneous loss of single-failure protection in any safety-related system. This was identified as an open issue in the DSER.

In a letter dated January 24, 1992, EPRI stated that it did not consider a requirement specifying that a loss of a dc bus caused by a failure other than a battery or battery charger failure would not result in a plant trip justified. EPRI reasoned that (1) the probability of such failure is very low, (2) the dc system can be operated with at least one fault to ground on each separate bus, and (3) such a requirement will result in additional costs and complexities. The staff concludes that EPRI's response in this regard is still unacceptable. The staff also notes that EPRI has committed to meet the requirements of IEEE 603-1980 and 308-1980. These standards include a single failure criterion that could be satisfied by a design in which a loss of a dc or ac bus would not result in a plant trip or a forced shutdown. Therefore, during its reviews of individual applications for FDA/DC, the staff will require that the plant designers perform an analysis of their ac and dc distribution systems to ensure that loss of any ac or dc bus does not result in a plant transient and simultaneous loss of single-failure protection in any safety-related system. On this basis, the DSER open issue is closed.

7.2.2 Allowed Outage Times for DC Safety Buses in ALWR Evolutionary Plant Technical Specifications

Section 7.3.1.4 of Chapter 11 specifies that provisions will be made in the PWR plant design to connect each dc bus to a standby, backup dc source (i.e., a combination of a battery and a battery charger). For the BWR plant, this section originally stated that backup dc sources for the Class 1E dc buses will not be required, provided continuous plant operation at 100-percent power with any one Class 1E battery or battery charger out of service is permitted for at least 72 hours. In its letter dated April 10, 1990, the staff requested that EPRI clarify what it meant by "permitted for at least 72 hours."

In its letter dated July 23, 1990, EPRI stated that the provision in Section 7.3.1.4 of Chapter 11 for the BWR plant should be interpreted as referring to the operation of the plant as allowed by technical specifications (limiting conditions for operation). EPRI explained that this provision is intended to account for possible changes to existing technical specifications as a result of the higher redundancy of safety divisions provided by the ALWR design for the BWR plant. EPRI has modified Section 7.3.1.4 of Chapter 11 would be modified to clarify its intent. The staff concludes that this is acceptable.

Nevertheless, during its review of the ALWR evolutionary plant technical specifications of an individual application for FDA/DC, the staff will evaluate the acceptability of a 72-hour allowed outage time for a battery or battery charger in a BWR ALWR evolutionary plant.

7.2.3 Security

The dc and low-voltage vital ac power supply systems also will feed safety loads and fit the definition of vital equipment in Section 5.2.1.1 of Chapter 9 of the Evolutionary Requirements Document.

The staff concludes that the requirements in the Evolutionary Requirements Document do not conflict with the requirement that the dc and low-voltage vital ac power supply systems be located in a vital area. Therefore, these requirements are compatible with NRC requirements and are acceptable.

Uninterruptible Power Supply for Security Equipment

Section 7.3.3.4 of Chapter 11 identifies the non-safety systems that will be provided with uninterruptible power. It originally included security lighting.

In its letter dated May 24, 1989, the staff requested that EPRI determine whether the requirement also should include uninterruptible power for other security equipment (e.g., security card readers, access control computer, alarm systems, and closed-circuit television) to answer consistency with the requirements of Chapter 9 of the Evolutionary Requirements Document.

In its letter dated September 15, 1989, EPRI agreed to revise Section 7.3.3.4 to read: "...including plant computers, instrumentation and control loads, security systems including security lighting, and fire detection systems." In its DSER for Chapter 11, the staff concluded that this revision was acceptable and that it would confirm that it was acceptably incorporated into the next revision of the Evolutionary Requirements Document. This was identified as a confirmatory issue.

Subsequently, EPRI revised Chapters 9 and 11 of the Requirements Document to specify a separate dedicated onsite security power supply, instead of including the security system as one of the plant permanent non-safety loads. As discussed in Chapter 9 of this report, the staff concludes that this is acceptable; therefore, this DSER confirmatory issue in Chapter 11 is closed.

7.2.4 Backup AC Power Sources for Safety-Related Uninterruptible Power Supplies

Figures 11.7-1 and 11.7-2 in Chapter 11 show a common backup ac power source (regulating transformer) between the channel A inverter and the channel B inverter. A common backup power source also is shown between the channel C inverter and the channel D inverter. The inverters will be labeled as having a static switch enclosed, and Section 7.4.4.2 of Chapter 11 indicates that these switches will be provided for automatic transfer of the loads to the backup ac power source on failure of the inverter. Such an automatic transfer scheme of independent channels to a common backup source can jeopardize the independence of the channels. The transfer scheme should either be made totally manual, utilizing redundant isolation devices (combination of two open switches or circuit breakers) between the channels at all times, or separate backup ac power sources should be provided for each channel. The staff will review applications for FDA/DC to ensure they are acceptable in this regard.

7.3 Conclusion

The staff concludes, with the exceptions noted above, that the requirements in Section 7 of Chapter 11 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and guidance and are acceptable.

8 NORMAL AND EMERGENCY LIGHTING

8.1 Function and Description

Section 8 of Chapter 11 of the Evolutionary Requirements Document provides design criteria for all onsite systems that will provide artificial illumination for rooms, spaces, and outdoor areas of the plant. These systems will include a normal station lighting system, a security lighting system, and an emergency lighting system. Section 8.2.1 of Chapter 11 states that illumination will be provided for each area of the plant in accordance with the guidelines of the IES Lighting Handbook, as published by the Illumination Engineering Society at the time the plant is designed.

EPRI states that the normal station lighting system will be used to provide normal illumination under all plant operating, maintenance, and test conditions. Section 8.3.3 of Chapter 11 states that the normal lighting system will be part of the plant's permanent non-safety systems and, as such, will be energized as long as power from an offsite power source or the standby non-safety source (CT generator) is available.

The security lighting system will provide illumination required to monitor security-related areas. Section 8.4.1 of Chapter 11 limits the uninterruptible power requirement for security lighting to those portions of the security lighting that are essential to plant protection following interruption of normal power. The rest of the security lighting system will be powered from the dedicated security power generator specified in Section 5.2.12.4 of Chapter 9. Section 8.4.2 of Chapter 11, as modified by EPRI's January 24, 1992, letter, requires that the security lighting illumination level be designed to be compatible with security monitoring equipment, and provide a minimum illumination of 1 foot-candle in selected areas, such as the isolation zone, with a minimum of 0.2 foot-candle elsewhere in the protected area.

The emergency lighting system will be used to provide acceptable levels of illumination throughout the station and, particularly, in areas where emergency operations will be performed, such as control rooms, battery rooms, and the containment, on loss of the normal lighting system. Section 8.5.1 of Chapter 11 specifies that the emergency lighting system will provide an illumination level of at least 10 foot-candles at all workstations in the plant where emergency operations will be performed that could require the reading of printed or written material or of scales and legends. In other areas of the plant, EPRI requires the emergency lighting to be able to achieve a minimum illumination level of 2 foot-candles.

Section 8.5.2 of Chapter 11 states that emergency lighting in the main control room will be powered from the safety uninterruptible (ac/dc) power supply. Outside the main control room, emergency lighting will be provided by dc self-contained, battery-operated units. The dc self-contained, battery-operated lighting units will be sized to provide at least 8 hours of operation at rated load.

The necessity to enter high radiation areas on a frequent basis to relamp burned out lighting fixtures can be a source of unnecessary personnel radiation exposures. In an effort to reduce the doses associated with relamping and maintenance of lighting fixtures, the plant designer will locate lighting fixtures in low radiation zones, use long-life lighting, and provide easy access to lighting fixtures. These features meet the intent of Regulatory Guide 8.8 to maintain occupational doses as low as is reasonably achievable and are acceptable.

8.2 Evaluation

8.2.1 Comparison of the ALWR Lighting System Requirements With Current Lighting System Design

The staff has determined that Section 8 of Chapter 11 does not include lighting from a Class 1E distribution system that can be powered from the Class 1E diesel generators in safety-related areas outside the control room and the access routes to those areas. Many current plant designs include this feature.

The normal lighting system provided in the ALWR design criteria will be part of the plant permanent non-safety systems and, as such, will be powered from the standby CT generator or, alternately, from the Class 1E diesel generators. This is an improvement over past designs; however, the design of the distribution system (power panels, feeders, motor control centers, etc.) to the lighting is all non-Class 1E. No part of the distribution system that will supply continuous lighting outside the control room is required to be qualified Class 1E. The only qualified lighting outside the control room will be provided by dc self-contained, battery-operated lights (good for at least 8 hours). The staff is concerned that, following seismic event with a resulting loss of the non-seismic, non-Class 1E distribution systems, all lighting outside the control room could be lost after 8 hours. In addition, reliance for continuous lighting in safety-related areas outside the main control room must be placed on an unqualified distribution system during non-seismic events.

In its letter dated April 10, 1990, the staff informed EPRI that lighting in safety-related areas outside the main control room and the access routes to those areas should be provided from the Class 1E distribution systems powered from Class 1E diesel generators. The distribution systems should, as a minimum, be qualified as Class 1E up to the lighting fixtures, and the lighting fixtures themselves should, as a minimum, be seismically supported (if the fixtures can be seismically qualified, they should be so qualified). The staff concluded that these qualification requirements should be specified in Section 8.5.2 of Chapter 11. This system should be provided in addition to the dc self-contained, battery-operated lighting units.

In its letter dated July 23, 1990, EPRI stated that the assumptions made by the staff that led to the proposal to require a Class 1E lighting distribution system do not appear sufficiently plausible to support the proposed requirement. EPRI stated that the assumption of a need for extensive activities outside the main control room beyond 8 hours following a seismic or non-seismic design-basis event is not consistent with EPRI's design criterion, which is based on (1) ensuring the main control room is habitable and fully operable if a seismic event should occur and the necessary actions to maintain safety and protect the public involve the use of Class 1E equipment and systems that can be operated from the control room and (2) ensuring a low probability of loss-of-power events that last more than 8 hours. EPRI stated that little or no activity is expected outside the control room beyond 8 hours, unless it is assumed that conditions are such that Class 1E equipment does not survive. Under this assumption, the provision of a Class 1E lighting distribution system cannot be counted on.

EPRI further stated that the staff's assumption of massive failure of the normal lighting system following an earthquake is not consistent with the actual performance of normal power distribution equipment during actual earthquakes, as documented in the Seismic Qualification Utilities Group (SQUG) program. EPRI stated that these data show that if electrical equipment is properly anchored, it has a high probability of surviving an earthquake. However, the data also demonstrate that lighting fixtures have been damaged and have fallen and represent a personnel and equipment hazard. EPRI's solution is to use safety wire ties to prevent fixtures from falling.

EPRI concluded that its approach of providing independent, self-contained, battery-operated lights in addition to continuous lighting in the control room provides high assurance that the necessary lighting will be available so that all activities required to respond to both seismic and non-seismic emergency conditions in the unlikely event that normal lighting is completely lost can be performed. EPRI stated, however, that a requirement will be added for lighting fixtures in normally occupied areas or over safety-grade equipment so that the structures are supported so they will not fall and present a hazard during seismic events.

The staff also is concerned about events other than seismic events. Experience at operating plants has shown that some events are often complex and require that operators be dispatched into the plant to perform some action (e.g., reposition a valve or verify its position, check protective relay flags and reset if necessary, or verify operation of a pump). Chapter 10 of the Evolutionary Requirements Document identifies controls that will be located locally in the plant that operators may have to attend to. The EPRI ALWR design requirements, however, would allow continuous lighting outside the main control room to be provided only from a non-safety system for which there are few specific separation requirements and no specific requirements for providing protection from the effects of design-basis events such as high-energy line breaks outside the containment.

In addition, EPRI's statement that the ALWR design criterion ensures a low probability of loss-of-power events lasting more than 8 hours appears to be derived from the EPRI requirements to cope with a station blackout for 8 hours. The station blackout scenario, however, does not include the occurrence of seismic or design-basis events. Non-safety switchgear or power panels that power normal lighting and are damaged by the effects of a seismic or design-basis event with no station blackout will likely remain unavailable for more than 8 hours (regardless of the availability of offsite or standby power sources). The attendant loss of lighting could potentially hinder the ability of the operators to respond to the event.

The staff also is concerned about the lack of requirements regarding the proper anchoring of electrical equipment to ensure a high probability of the equipment surviving an earthquake. EPRI references data from the SQUG program to support its position that massive failure of the normal lighting system following an earthquake is unlikely. The staff concludes that there is no assurance that significant portions of the normal lighting system will not be damaged during an earthquake without implementing acceptable design criteria. Although EPRI admits that lighting fixtures have been damaged and have fallen during seismic events, its proposes only to use safety wire ties to prevent them from falling, not necessarily to enhance their survival following a seismic event.

In the DSER for Chapter 11, the staff concluded that EPRI should identify the criteria in the Evolutionary Requirements Document that provide for a design wherein the safety-related systems necessary to mitigate the consequences of design-basis events and to bring the plant to a safe condition can all be operated from the main control room. In addition, for the continuous lighting systems in safety-related areas and the access routes to those areas, EPRI should provide design criteria that demonstrate that reasonable measures have been taken to address seismic survivability and the loss of lighting in those areas as a result of the effects of design-basis events. The Evolutionary Requirements Document should also specify that the continuous lighting systems in such areas will be powered from redundant electrical divisions and that they will be capable of being powered from the Class 1E diesel generators. These provisions should be made in addition to the use of dc self-contained, battery-operated lighting units. This was identified an open issue in the DSER.

Subsequently, EPRI added a provision that particular attention will be given to the supports and anchoring of lighting fixtures and other components of the lighting systems located in normally occupied areas or in areas containing safety equipment so as to enhance the survivability of the components during an earthquake. EPRI also added a requirement that the emergency lighting installations, which will serve the main control room and those other areas of the plant where safe shutdown operations may be performed, be designed to remain functional during and after a design-basis earthquake. Finally, EPRI required that circuits to individual lighting fixtures be staggered as much as possible, with the staggered circuits fed from separate electrical divisions.

These additional requirements strengthen the seismic provisions for the lighting systems and enhance the redundancy of the lighting, but they do not provide a level of available lighting for safety-related areas outside the main control room that is comparable to the safety systems they light. Because of their typically poor lighting quality and limited duration, the emergency lighting installations outside the main control room (8-hour battery packs) are suitable only as transitional lighting sources to provide lighting until continuous lighting is reestablished, or when all ac lighting has been lost. The normal ac lighting system, as specified by EPRI on the other hand, provides continuous, better quality lighting, but it is supplied from a non-Class 1E distribution system that is vulnerable to effects that the Class 1E systems are protected against.

The staff, therefore, concludes that at least a portion of the continuous ac lighting in safety-related areas outside the main control room and in the access routes to those areas should be provided from a Class 1E distribution system capable of being powered from a Class 1E diesel generator. The lighting transformers and their associated lighting panels should be Class 1E and seismic Category I. The lighting circuits up to the lighting fixtures should be treated as Class 1E and routed in seismic Category I raceways. The lighting fixtures themselves should, as a minimum, be seismically supported. The circuits to individual lighting fixtures should be staggered with the staggered circuits fed from separate electrical divisions. One of the circuits feeding the lighting fixtures should be supplied from the Class 1E distribution system. The other circuit to the fixtures should be supplied from a separate non-Class 1E electrical division backed up by the combustion turbine generator. The staff will pursue these details of the lighting system design with the ALWR plant designers during its review of an individual application for FDA/DC in accordance with the criteria in SRP Section 9.5.3. Therefore, the DSER open issue is closed.

8.2.2 Normal Lighting System

Section 8.3.3 of Chapter 11 specifies that the normal lighting system will be considered part of the plant permanent non-safety systems and, as such, must be energized as long as power from an offsite power source or the standby non-safety power source is available. Section 4.2.6 of Chapter 11 specifies that the medium-voltage ac distribution system will be designed to permit feeding the permanent non-safety loads from the onsite standby safety power sources (diesel generators) following a manual load transfer process. Consistent with these requirements and the original staff position given in Section 8.2.1 of its DSER for Chapter 11, the staff stipulated that Chapter 11 of the Evolutionary Requirements Document also should require that, as a minimum, the portions of the normal lighting system that will provide lighting to safety-related areas and equipment and their access routes be capable of being powered from the diesel generators following a manual load transfer process. This was part of the open issue discussed in Section 8.2.1 above.

EPRI has not provided any additional requirements regarding access of the normal lighting system to the diesel generators. The staff stipulates, however, in Section 8.2.1 above, that at least a portion of the continuous ac lighting in safety-related areas outside the main control room and in the access routes to these areas should be provided from a Class 1E distribution system capable of being powered from a Class 1E diesel generator. The staff also stipulates that a second lighting circuit supplied from a non-Class 1E division backed up by the combustion turbine generator should also be provided in safety-related areas and their access routes. These staff positions obviate the need for any additional requirements regarding access of the normal lighting system to the diesel generators. The staff will review individual applications for FDA/DC to ensure that vendors provide these features in their standard designs. This portion of the DSER open issue is, therefore, closed, consistent with the staff position identified in Section 8.2.1 above.

In addition, Section 8.3.5 of Chapter 11 of the Evolutionary Requirements Document originally specified that the circuits to the individual lighting fixtures in the normal lighting system would be staggered as much as possible to ensure some lighting is retained in a room in the event of a circuit failure. In the DSER for Chapter 11, the staff stated that, consistent with its position in Section 8.2.1 above, Section 8.3.5 of Chapter 11 of the Evolutionary Requirements Document also should require that, as a minimum, the staggered circuits to lighting fixtures in safety-related areas and their access routes be supplied from redundant electrical divisions capable of being powered from the diesel generators. This also was identified as part of the open issue in Section 8.2.1.

Subsequently, in Chapter 11 of the Evolutionary Requirements Document, EPRI amended the staggering requirement so that circuits to individual lighting fixtures in the normal lighting system will be staggered as much as possible, with the staggered circuits fed from separate electrical divisions. Although, as indicated above, EPRI did not provide any additional requirements regarding access of the normal lighting system to the diesel generators, the staff positions identified in Section 8.2.1 above obviate the need for any such requirements. The staff will review individual applications for FDA/DC to ensure that vendors provide these features in their standard designs in accordance with the criteria in SRP Section 9.5.3. This portion of the DSER open issue is, therefore, closed, consistent with the staff position identified in Section 8.2.1 above.

8.2.3 Emergency Lighting

Section 8.5.1 of Chapter 11 originally required that the emergency lighting system provide illumination units of at least 10 foot-candles in those areas of the plant where emergency operations will be performed that could require the reading of printed or written material or of scales and legends. In the DSER for Chapter 11, the staff concluded that the wording of this requirement was confusing and could be interpreted to mean that illumination units (such as battery-operated lighting units) will be provided that can put out 10 foot-candles of illumination at their source. The staff concluded that Chapter 11 should be clarified to specify that the lighting provided will achieve a minimum illumination of 10 foot-candles at the printed or written material and on scales and legends. This was identified as an open issue.

Subsequently, EPRI revised Section 8.5.1 in Chapter 11 to require that the emergency lighting system provide a minimum illumination level of 10 foot-candles at all workstations in the plant where emergency operations will be performed that could require the reading of printed or written material or the reading of scales and legends. With regard to the lighting intensity, the new revision is acceptable since it is now clear that the requirement is specifying an illumination level for the lighted area rather than the source strength for the emergency lighting units. With regard to the areas to which the requirement applies, the revision is acceptable with the understanding that the requirement is not limited to control rooms or local control stations but applies, in general, to the areas of the plant where emergency operations will be performed that require the reading of printed or written material. In a letter dated January 10, 1992, EPRI stated that this was the case. The staff, therefore, concludes that this open issue is closed.

Section 8.5.2 of Chapter 11 requires that the emergency lighting be accomplished by the following systems:

- main control room: emergency lighting system fed from safety uninterruptible (ac/dc) power supply
- outside main control room: dc self-contained, battery-operated lighting units

The requirement for the emergency lighting in the main control room could be interpreted to mean that one uninterruptible power supply would be sufficient to power that lighting. As a result, in the DSER for Chapter 11, the staff stated that this requirement should be clarified to require that two independent safety uninterruptible power supplies fed from redundant safety divisions be provided to power the emergency lighting. This was considered necessary to ensure that the emergency lighting meets the single-failure criterion. In addition, the qualification of the emergency lighting system was not clear. The staff concluded in its DSER for Chapter 11 that the Evolutionary Requirements Document should specifically require that the emergency lighting system be qualified to ensure that adequate lighting remains operable following a seismic event. These two aspects of the emergency lighting design were identified as an open issue.

Subsequently, EPRI added two new sections in Chapter 11 (Sections 8.5.4 and 8.5.5) to address these two issues. Section 8.5.4 requires that the emergency lighting system of the main control room be integrated with the normal lighting system and be designed so that alternate emergency lighting fixtures are fed from separate safety divisions. In the rationale portion of this section, EPRI states that the emergency lighting circuits should be staggered, with the staggered circuits fed from separate safety divisions so as to ensure that adequate lighting is retained in the main control room in the event of a circuit failure. The staff concludes that the new provisions in combination with the requirements in existing Section 8.5.2 require an ALWR designer to provide two separate and independent safety power supplies fed from redundant safety divisions to power the emergency lighting in the main control room. This acceptably resolves the aspect of this open issue regarding redundancy of the emergency lighting system in the main control room. The staff is not entirely clear, however, how the emergency lighting system in the main control room will be integrated with the normal lighting system as required in the new Section 8.5.4 of Chapter 11. If some fixtures in the main control room are fed from, and part of, the normal lighting system while other fixtures are separately fed from, and part of, the emergency lighting system, with the combination providing the normal control room illumination levels as the staff believes is the intent of the requirement, this would likely be an acceptable design. If, however, the integration is done by normally powering all the fixtures in the control room from the normal lighting system and then switching a portion to the emergency lighting supply on loss of the normal lighting supply, serious separation issues could be involved. The staff will review this aspect of the lighting system in its review of an individual application for FDA/DC.

With regard to the qualification of the emergency lighting, new Section 8.5.5 of Chapter 11 requires that the emergency lighting installations that will serve the main control room and those other areas of the plant where safe shutdown operations may be performed be designed to remain functional during and after a design-basis earthquake. This requirement, in conjunction with the staff's requirement to supply at least a portion of the safety-related continuous ac lighting outside the main control room from a Class 1E distribution system (Section 8.2.1 of this chapter), acceptably resolves the portion of the DSER open issue regarding qualification of the emergency lighting system. EPRI has adequately addressed both aspects of the open issue in the DSER. Therefore, this open issue is closed.

In its letter dated June 8, 1989, the staff stated that it was unclear whether the 8-hour battery-powered emergency lights would be installed in high-radiation areas or outdoor locations. The staff's concern resulted from difficulties that existing plants have had with such installations. In its letter dated October 19, 1989, EPRI responded that the 8-hour battery-powered emergency lights will be installed throughout ALWRs referencing the Evolutionary Requirements Document, as necessary, in accordance with the guidance of SRP Section 9.5.1, "Fire Protection Program," in all areas needed for the operation of safe-shutdown equipment and in the access routes leading to these areas. In addition, similar lighting units with at least a 1.5-hour battery power supply will be provided throughout the plant to ensure personnel safety and property protection in accordance with the requirements of the Life Safety Code and the National Electric Code. EPRI also stated that although specific high-radiation areas or outdoor locations that may require battery-powered emergency lights are not addressed in the Evolutionary Requirements Document, it expects that some units may be required in outdoor locations, but few, if any, in high-radiations areas.

EPRI committed to include a statement of compliance with SRP Section 9.5.1, the Life Safety Code, and the National Electric Code in Chapter 1 of the Evolutionary Requirements Document. The staff concluded that this response was acceptable and would confirm that this matter was satisfactorily addressed during its review of revisions to the Evolutionary Requirements Document. This was identified as a confirmatory issue in the DSER.

EPRI has added Section 8.5.6 to Chapter 11 of the Evolutionary Requirements Document, which requires that additional dc self-contained battery-operated lighting units be installed throughout the plant to provide emergency lighting for personnel safety in accordance with the National Electric Code and the Life Safety Code of the National Fire Protection Association. Additionally, EPRI has committed to comply with SRP Section 9.5.1 (see Table B.1-2 of Appendix B to Chapter 1 of the Evolutionary Requirements Document). Because EPRI has met its commitment to make these revisions, this confirmatory issue is closed.

8.2.4 Security Lighting System

Section 8.4.1 of Chapter 11 requires that the non-safety batteries provide at least 30 minutes of continued operation of the security lighting system in the event of an interruption of ac power. Because this exceeds current regulatory requirements and provides sufficient time to load security lighting onto the dedicated backup power supply, the staff concludes that this is acceptable.

Section 8.4.2 of Chapter 11 requires that the security lighting system be designed to provide a minimum illumination of 0.2 foot-candle. Revision 3 to Section 8.4.2 of Chapter 11, as modified by EPRI's letter of January 24, 1992, requires that the security lighting system be designed to provide a minimum illumination level of a 1 foot-candle when measured horizontally at ground level. Section 8.4.2 also states that higher illumination levels may be necessary in certain areas, such as portals and vital areas, to provide adequate monitoring capability. Because the requirement for a minimum illumination level of 1 foot-candle is in excess of the 0.2 foot-candle required by 10 CFR Part 73, this requirement is acceptable.

However, experience has shown that inattention to the integration of exterior lighting systems with the isolation zone's closed-circuit television (CCTV) system, particularly uniformity of lighting (e.g., light sources or reflections in the field of view, glare, blooming, and excessive light/dark ratios) can be detrimental to alarm assessment. In its letter dated September 15, 1989, EPRI stated that light/dark ratio was an engineering detail beyond the scope of the Evolutionary Requirements Document. The staff concludes that this response is acceptable. However, it will determine if the integration of the exterior lighting systems with the CCTV system is acceptable when it emulates a site's security system during the review of an individual application for FDA/DC.

The staff concludes that the requirements in Section 8 of Chapter 11 are consistent with the requirements of 10 CFR 73.55(c)(5) for security lighting.

8.3 Conclusion

The staff concludes, with the exceptions noted above, that the requirements in Section 8 of Chapter 11 of the Evolutionary Requirements Document do not conflict with current regulatory requirements and guidance and are acceptable.

9 ELECTRICAL PROTECTIVE SYSTEMS

9.1 Functions and Description

Section 9 of Chapter 11 of the Evolutionary Requirements Document provides the design and performance requirements for the station grounding systems, surge protection systems, cathodic protection systems, and heat tracing systems.

The plant grounding systems will be designed to provide protection to personnel and equipment under normal and abnormal conditions. The major functions of the systems can be summarized as follows:

- to protect personnel by eliminating or reducing shock hazards
- to protect equipment by minimizing transient overvoltages
- to provide low impedance path to ground for ground fault currents, lightning discharges, and switching surge currents and to facilitate protective relaying for fast clearing of ground faults
- to stabilize circuit potential and to provide voltage reference for control and instrumentation systems

The plant grounding systems will include

- ground mats that will provide low resistance interface with the earth
- plant electrical distribution system grounding equipment that will be used to connect the electrical system's neutrals to ground
- equipment and structure grounding equipment that will be used to connect structures and equipment enclosures to ground
- instrumentation and control grounding equipment

The surge protection systems will be designed to protect plant equipment from exposure to overvoltage transients resulting from lightning strikes and switching operations. These systems will include surge arrestors and capacitors and lightning protection equipment.

The cathodic protection system will provide corrosion control of underground and submerged metallic surfaces. It will be used to protect buried pipes, tanks, and other metallic equipment in contact with potentially corrosive sprays, water, and dissimilar metals against long-term degradation in order to avoid or reduce repair or replacement costs and plant shutdowns.

The electrical heat tracing system will be designed to provide effective heating of fluids required for normal and transient plant operation. It will be applied to plant fluid systems, including piping, pumps, strainers, valves, and tanks, and will consist of electric heating cables, temperature controllers, power supplies, alarm and monitoring devices, and associated hardware.

9.2 Conclusion

The staff concludes that the requirements in Section 9 of Chapter 11 of the Evolutionary Requirements Document are consistent with regulatory requirements and are acceptable.

10 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 11 of the Evolutionary Requirements Document for the design of electric power systems do not conflict w th current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine that the plant-specific design, operation, and arrangement of the electric power systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the Standard Review [n, or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 11 specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose electric power systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A to Chapter 11 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
GENERIC SAFETY AND LICENSING ISSUES

The original version of the Evolutionary Requirements Document presented EPRI's requirements to address the resolution of generic safety issues (GSIs) in Appendix B of each chapter. In the DSER for Chapter 11 of the Evolutionary Requirements Document, the staff evaluated EPRI's requirements to address the resolution of the following GSIs:

- 91, "Main Crankshaft Failure in Transamerica Delaval Emergency Diesel Generators"
- 107, "Generic Implications of Main Transformer Failure"
- 128, "Electrical Power Reliability"

The staff concluded that EPRI's requirements to address GSI 91 were acceptable and identified open issues associated with GSIs 107 and 128.

In Revision 1 of the Evolutionary Requirements Document, submitted by letter dated September 7, 1990, EPRI relocated its requirements to address GSIs that were unresolved as of January 1, 1990, to Appendix B to Chapter 1. As a result, a number of GSIs that were addressed in the original Evolutionary Requirements Document are no longer addressed. The staff has provided its evaluation of EPRI's requirements to address GSIs in Appendix B to Chapter 1 of this report. The staff has also documented its closure of open and confirmatory issues associated with generic safety issues no longer addressed by EPRI in Appendix B to Chapter 1 of this report. Therefore, the DSER open issues associated with GSIs 107 and 128 are closed.

APPENDIX C
REGULATORY DEPARTURE ANALYSIS

In the DSER for Chapter 11 of the Evolutionary Requirements Document, the staff provided (as Appendix C) a regulatory departure analysis for the issues identified in SECY-91-078. As stated in Section 1.3 of this chapter, the staff has not identified any additional policy issues during its review of Chapter 11.

CHAPTER 12, "RADIOACTIVE WASTE PROCESSING SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 12, "Radioactive Waste Processing Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 12 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by ABB Combustion Engineering Nuclear Power; Bechtel Power Corporation; Duke Power Company; General Electric Company; Grove Engineering, Inc.; J. Vance and Associates; MPR Associates, Inc.; S. Levy Incorporated; Sargent and Lundy Engineers; Stone and Webster Engineering Corporation; Westinghouse Electric Corporation; and EPRI.

On December 23, 1988, EPRI submitted the original version of Chapter 12 of the Evolutionary Requirements Document for staff review. By letters dated March 22 and May 24, 1989, and July 13 and August 22, 1990, the staff requested that EPRI supply additional information. EPRI provided the information in its responses dated August 18 and September 15, 1989, and January 18, 1990.

On January 15, 1991, the staff issued its DSER for Chapter 12 of the Evolutionary Requirements Documents. On May 29, 1991, the staff and EPRI met with the Advisory Committee on Reactor Safeguards ACRS Subcommittee on Improved Light Water Reactors to discuss Chapter 12, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 12, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 12 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 12

Chapter 12 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the radioactive waste processing systems.

The key topics addressed in the Chapter 12 review include EPRI-proposed design requirements for

- gaseous radioactive waste processing systems
- liquid radioactive waste processing systems
- solid radioactive waste processing systems

- demineralized water and condensate systems
- support systems for the processing systems

1.3 Policy Issues

During its review of Chapter 12 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 12 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) fuel source term parameters (2.2.2)

(2) process and effluent radiological monitoring instrumentation and sampling systems (2.2.9)

(3) fire protection requirements (2.2.10 and 3.3.6)

(4) use of turbine seal steam (3.3.1)

(5) use of high-efficiency particulate air (HEPA) filters downstream of charcoal adsorbers (3.3.3)

Confirmatory Issues

(1) use of reasonably demonstrated technology to reduce population doses (2.2.1)

(2) transfer of gaseous radioactive waste discharge to plant vent through the heating, ventilating, and air conditioning systems (3.3.2)

(3) potentially explosive mixtures of hydrogen and oxygen (3.3.4)

(4) configuration of charcoal adsorber beds (3.3.5)

(5) shipping container design (5.5)

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All outstanding issues identified in the DSER for Chapter 12 have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.12.V-1 inputs and releases from the radioactive waste processing systems (2.2.1)

E.12.V-2 use of demonstrated technology (2.2.1)

E.12.V-3 offsite dose calculation manual (2.2.1)

E.12.V-4 fuel source term parameters for design of radioactive waste processing systems (2.2.2)

E.12.V-5 estimate of personnel radiation exposure (2.2.4)

E.12.V-6 control, monitoring and sampling of liquid and radioactive waste processing and effluent streams (2.2.9)

E.12.V-7 interface between BWR HVAC systems and GRWP systems (3.3.2)

E.12.V-8 use of HEPA filters downstream of charcoal adsorbers (3.3.3)

E.12.V-9 potentially explosive mixtures of hydrogen and oxygen (3.3.4)

E.12.V-10 piping layout and design and operating procedures for filters and ion exchangers in liquid radioactive waste processing systems (4.2)

E.12.V-11 shipping container design (5.5)

2 POLICY STATEMENTS AND KEY REQUIREMENTS

Chapter 12 of the Evolutionary Requirements Document specifies requirements proposed by EPRI for the radioactive waste processing systems that are applicable to ALWRs. Generally, the gaseous and liquid radioactive waste processing systems will connect to and receive radioactive gas and liquid from those plant systems and components containing potentially radioactive gases and liquids, which require removal for processing or disposal, and terminate at recycle or environmental discharge points or radioactive solid radioactive waste system interfaces. Although plant heating, ventilating, and air conditioning (HVAC) systems will collect, filter, and discharge radioactive effluents, EPRI does not consider them as gaseous radioactive waste processing systems. The EPRI design requirements for HVAC systems are discussed in Chapter 9 of the Evolutionary Requirements Document.

Solid radioactive waste processing systems will begin with the discharge of potentially radioactive solids from processing equipment (e.g., cartridge filter vessels, charcoal adsorbers, and high-efficiency particulate air filters), from points of collection of dry radioactive wastes resulting from operation and maintenance activities, and from the points of discharge of radioactive resin slurries and sludges from the liquid radioactive waste processing system. The solid radioactive waste processing system will terminate at the location where solid radioactive wastes are shipped off site.

2.1 Policy Statements

Section 1.5 of Chapter 12 of the Evolutionary Requirements Document contains those policies established by the ALWR Utility Steering Committee related to the design approach to be used in the development of the gaseous, liquid, and solid radioactive waste processing systems.

Section 1.5.1 of Chapter 12 states that the volumes of low-level dry and wet wastes will be equal to or less than corresponding volumes produced by the 10-percent best plants of the same type (BWR, PWR) currently operating in the United States. In addition, this section specifies that the total radioactivity in curies (excluding tritium) released from an ALWR plant via liquid and gaseous effluents will be equal to or less than the corresponding quantities released from the 10-percent best plants of the same type currently operating in the United States.

Section 1.5.2 of Chapter 12, as amended in Revision 3, states that the fuel source terms specified by EPRI to be used in the design of the radioactive waste processing systems provide the bases for the values used for the design of these systems (e.g., evaluation of 24-hour offsite radioactive nuclide concentrations in effluents in accordance with the limits specified in 10 CFR Part 20), and the values used for the evaluation of the performance of the radioactive waste processing systems (evaluation of offsite releases during normal plant operation, including anticipated operational occurrences, and of annual average offsite does in accordance with the guidelines in 10 CFR Part 50, Appendix I).

Section 1.5.3 of Chapter 12 describes attributes for the baseline design and design options for liquid radioactive waste processing systems (LRWPSs) for the ALWRs. This section requires that the design basis for the LRWPS permit releases of radioactive liquids well below regulatory restrictions under expected conditions. The optional design is identified as one that will accommodate "zero liquid release" and is to be used for sites where no radioactive liquid release to the environment from the plant will be allowed. This section notes that the optional design at such sites may require additional processing equipment, both for the liquid and solid radioactive wastes, such as waste evaporators and associated waste solidification equipment.

Section 1.5.4 of Chapter 12 lists those features that would allow the radioactive waste processing systems to meet the objectives and goals of EPRI's ALWR program. These features include requirements proposed by EPRI for fuel performance, delay times for release of gaseous effluents, use of filtration and ion exchange technology in liquid radioactive waste processing systems, reduction of irregular and unplanned leakage inputs through design considerations, consideration of the need to maintain a balance of the radioactive water within the plant, a need to maintain a plant tritium balance, and minimization of the generation of wet and dry solid wastes and the processing techniques that reduce the volumes of such wastes.

Section 1.5.5 of Chapter 12 lists the features that EPRI has determined will contribute to the reduction of radiation exposure to personnel working in the radioactive waste processing areas so that it will be as low as is reasonably achievable (ALARA) and will meet the EPRI-stated goal of no more than 100 person-rem per year for the plant. These features include (1) the design for remote centralized operation, (2) the selection and design of reliable and easily serviced equipment in order to minimize maintenance operations, (3) the use of remote handling equipment, and (4) consideration of the processing system configuration and radiation shielding locations.

Section 1.5.6 of Chapter 12 states that simplification will be achieved by the use of fewer pieces of equipment and less complicated equipment and controls. Charcoal adsorbers will be used at room temperature with humidity control achieved by cooling with the plant chilled water system. Gas decay tanks will be eliminated from the designs. Although EPRI concludes that evaporators should not be necessary and that processing should be performed through filtration and ion exchange, it has provided requirements for evaporators to be used on a case-by-case basis. EPRI further states that no solidification equipment is expected to be required and incinerators will not be included as a means of achieving the EPRI solid waste reduction goal.

Section 1.5.7 of Chapter 12 discusses the differences between BWRs and PWRs that affect radioactive waste processing system design.

Section 1.5.8 of Chapter 12 states that radioactive waste processing systems will be designed so that mobile equipment can be used and alternative internal processing paths will exist to accommodate future modifications.

Section 1.5.9 of Chapter 12 states that there is no expected need for long-term onsite storage of low-level radioactive waste. This section specifies that a minimum of 6 months of onsite storage space will be provided to accommodate unforeseen events and interruptions to the shipping of solid wastes. A portion of the space will be shielded to allow radioactive decay of the more radioactive wastes for up to 6 months to enable shipping under less stringent conditions.

Section 1.5.10 of Chapter 12 states that the gaseous, liquid, and solid radioactive waste processing systems will not be classified as safety systems. Therefore, EPRI requires features to ensure that highly radioactive fluids are not inadvertently transported to the radioactive waste processing systems under accident conditions.

2.2 Functions and Key Performance Requirements

Section 1.3 of Chapter 12 of the Evolutionary Requirements Document states that the overall functions of the radioactive waste processing systems will be as follows:

- To separately collect and segregate in sumps or tanks, as appropriate, gaseous, liquid, and solid radioactive or potentially radioactive wastes by connections to the various plant systems and drains serving radiation areas.
- To provide storage capability in order to accommodate process delays and disposal of processed wastes.
- To process the radioactive wastes in order to accumulate, remove, separate, reduce, or concentrate the radioactivity of the waste-containing streams or solids. The objective is to permit discharge, disposal, or recycling of the carrier stream and/or to permit packaging and offsite disposal of the resultant solid wastes.
- To safely and effectively process the wastes for safe, monitored discharge or disposal of effluents or solids from the station in compliance with the various State and Federal regulations regarding discharges, transport, and disposal and to meet the ALWR goals.
- To permit adequate sampling and/or in-line measurement of input, process, and discharge streams for input into a data processing system to provide the operator with information for control and decisionmaking regarding routing, processing, disposal, and unusual occurrences. The processed data will also be used for reporting purposes.
- To serve as the principal means for controlling the tritium concentration in the reactor coolant in PWR plants.
- To ensure high-integrity boundaries for radioactive fluids to preclude their uncontrolled release to the environment.

Key performance requirements applicable to gaseous, liquid, and solid radioactive waste processing systems specified by EPRI for all ALWRs are discussed in the following sections.

2.2.1 Goals of Radioactive Releases and Waste Reduction

Section 2.2.1 of Chapter 12 states that the radioactive waste processing systems will enable ALWR plant designs, which reference the Evolutionary Requirements Document, to meet the goals for reducing the radioactive releases and the volume of solid low-level waste from ALWRs. The plant designer is tasked with the responsibility of demonstrating that the expected inputs to the radioactive waste processing systems and processing methods will result in outputs that meet the objectives and goals of the Evolutionary Requirements Document. The staff will ensure that the plant-specific designs of the radioactive waste processing systems comply with the staff's regulations and regulatory guidance during its review of individual applications for FDA/DC.

One of the acceptance criteria for evaluating the design adequacy of the radwaste treatment systems for LWRs in SRP Sections 11.2, "Liquid Waste Management Systems," and 11.3, "Gaseous Waste Management Systems," is the inclusion in these systems of all items of reasonably demonstrated technology that can reduce population doses at a favorable cost-benefit ratio. This acceptance criterion is based on 10 CFR Part 50, Appendix I, Section II.D. In its response dated August 18, 1989, to a staff request dated March 22, 1989, for the status of compliance of ALWR radwaste treatment system designs with the above requirement, EPRI committed to revise the Evolutionary Requirements Document so that the designs are consistent with the SRP acceptance criterion. The staff concluded this was an acceptable commitment and identified it as a confirmatory issue in the DSER for Chapter 12.

In its response dated May 22, 1991, to the DSER, EPRI referenced Appendix B to Chapter 1 of the Evolutionary Requirements Document, which requires that the ALWR radwaste treatment system design comply with SRP Sections 11.2 and 11.3 and Regulatory Guide (RG) 1.110, "Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors." The guide addresses the use of available technology to reduce population doses and provides guidelines for performing a cost-benefit analysis for radwaste systems for LWRs. Tables B.1-1 and B.1-2 of Appendix B to Chapter 1, of the Evolutionary Requirements Document require that the ALWR radwaste treatment system design comply with 10 CFR Part 50, Appendix I; SRP Sections 11.2 and 11.3; and RG 1.110. The staff concludes that this is acceptable; therefore, this DSER confirmatory issue is closed. The staff will review individual applications for FDA/DC to determine compliance with SRP Sections 11.2 and 11.3 and RG 1.110. It will also review the offsite dose calculation manual (ODCM). However, the staff's review of the ODCM is not likely to occur until a plant design has been coupled with a site.

2.2.2 Source and Input Terms

Fuel source terms for the design and evaluation of radioactive waste processing systems are identified in Section 2.2.2 of Chapter 12 of the Evolutionary Requirements Document. These fuel source terms provide the bases for system design and the evaluation of expected operation and performance.

Section 2.2.2.1 of Chapter 12 states that activation product source terms will be consistent with those given in NUREG-0016, "Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents for Boiling Water

Reactors (BWR-GALE Code)," for BWRs and in NUREG-0017, "Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents for Pressurized Water Reactors (PWR-GALE Code)," for PWRs.

EPRI states that volumes and rates of release of gaseous and liquid radioactive wastes at the various source locations will be established on the basis of equipment performance characteristics; American Nuclear Society/American National Standards Institute (ANS/ANSI) 55.1, 55.4, and 55.6; and operating experience. Section 2.2.2.3 of Chapter 12 states that volumes of wet solid radioactive wastes will be derived from the performance parameters of the processes that produce them. Volumes of dry active solid radioactive wastes will be based on applicable operating experience.

In the DSER for Chapter 12, the staff identified the fuel source term parameters specified by EPRI in Chapter 12 as an open issue, since the parameters appeared to be inconsistent with the SRP criteria. Specifically, the staff referred to the fuel source term parameters given in Chapter 12 for (1) radwaste system design and shielding design, (2) evaluation of expected operation and performance, and (3) accident evaluation and establishment of technical specifications (TS).

In its May 22, 1991, letter responding to the DSER open issue, EPRI reiterated its original claim that the specified fuel source terms were consistent with the SRP criteria. Additionally, EPRI stated that accident, shielding, and TS design requirements currently provided in Chapter 12 would be deleted from that chapter and provided elsewhere in the Evolutionary Requirements Document. In justifying this approach, EPRI noted that Chapter 12 was dedicated to radwaste system design only. In subsequent revisions of Chapter 12, EPRI deleted the fuel source term requirements for accident evaluation, shielding design, and establishment of TS. Also, EPRI revised the fuel source terms for evaluating the performance of radioactive waste processing systems during normal operations, including anticipated operational occurrences.

Although the staff agrees with the approach of moving the requirements for fuel source terms for accident evaluation, shielding design, and establishment of TS from Chapter 12 to another chapter, EPRI's response regarding source terms is still inadequate. Although the 0.25-percent failed fuel specified by EPRI for an evolutionary PWR and 100,000 μCi/sec noble gas release rate at 30 minutes, decay for the off-gas system for an evolutionary BWR may be an adequate basis for shielding designs of ALWRs, such a basis is not adequate for designing radioactive waste processing systems for evolutionary ALWRs. This is because, unlike radwaste system design, shielding design is strongly dictated by corrosion products (these do not depend on failed fuel as fission products do) and in certain plant areas by the highly energetic nitrogen-16 (6.1 and 7.1 MeV) gammas. Moreover, operating plant experience indicates there are more problems arising from radwaste system designs than from shielding designs for quite a few reactors. Such problems in the past have resulted in unscheduled plant shutdowns or in release of radioactive materials to the environment that are greater than the dose limit objectives in 10 CFR Part 50, Appendix I. The staff recognizes that fuel performance has recently improved with better fuel fabrication. However, an adequate data base does not exist that shows significantly improved fuel performance of the more recently licensed reactors. Therefore, it is appropriate to design ALWR radwaste systems so that they have the capability to process liquid and gaseous radioactive wastes corresponding to 1-percent failed fuel for an evolutionary PWR and 100 μCi/sec-MWt noble gas release rate at 30 minutes' decay for the off-gas system for an evolutionary BWR in accordance with the criteria in SRP Sections 11.2 (Item III.2.C) and 11.3 (Item III.2.b). Further, the above basis should be used to (1) demonstrate compliance of concentrations of radionuclides in gaseous effluents and liquid effluents discharged to unrestricted areas with applicable 10 CFR Part 20 regulatory limits and (2) analyze the failure of gaseous radioactive waste processing systems to show that the system design meets the guidelines of Branch Technical Position ETSB 11-5, "Postulated Radioactive Releases Due to a Waste Gas System Leak or Failure" (SRP Section 11.3).

As part of "good neighbor policy," which sets goals more stringent than regulatory requirements, EPRI has specified two options for the fuel source term parameters in Table 12.1-1 of Chapter 12, either of which can be used by the ALWR evolutionary plant designer for evaluating radioactive waste processing system performance (i.e., expected annual release of radioactive materials to the environment via gaseous and liquid effluents and expected offsite radiation doses due to both liquid and gaseous effluents during normal plant operation, including anticipated operational occurrences). For such an evaluation, the Evolutionary Requirements Document specifies that the designer can use either (1) fuel source terms that are consistent with 0.025-percent failed fuel for a PWR or 15,000 μCi/sec noble gas release rate (30 minutes' decay) for the off-gas system for a BWR (first option) or (2) fuel source terms that are consistent with ANSI/ANS 18.1 for PWRs and BWRs (second option). However, if the designer elects to use the second option, EPRI requires the designer to check ANSI/ANS 18.1 for consistency with the source term bases given in the applicable NUREG report (NUREG-0016 or NUREG-0017). If the designer finds substantive differences, EPRI requires the designer to adjust the source term parameters given in ANSI/ANS 18.1 to be consistent with the NRC evaluations and then use the adjusted values. Regarding the first option, EPRI justifies it by stating that it reflects EPRI's objective to limit normal plant releases of radioactive nuclides to quantities measured for the top 10 percent (in terms of low releases) of the PWRs and BWRs during the years 1984 and 1985. EPRI believes that if all the design and operating techniques listed in Chapter 12, Appendix B, of the Evolutionary Requirements Document were followed to reduce the generation of radioactive wastes, achieving the above objective for an ALWR should be possible.

Although the staff recognizes the above goal as a worthy objective, it has determined that the first option for the source term is not acceptable for evaluating expected performance of the radioactive waste processing system for ALWRs because no extensive operating plant data base exists to support the EPRI expectation that only small radioactive waste releases will occur from ALWRs as long as the design and operating techniques listed in the Evolutionary Requirements Document in Chapter 12, Appendix B, are followed. Therefore, the staff considers that the source term bases specified in NUREG-0016, Revision 1, and NUREG-0017, Revision 1, should be used in accordance with SRP Sections 11.2 and 11.3 for evaluating expected annual releases of radioactive materials in gaseous and liquid effluents from ALWRs. The staff considers the bases in the NUREG reports appropriate because they reflect (1) measured reactor coolant concentrations of radioactive nuclides over an extended period for a large number of operating reactors, (2) a calculated average noble gas release rate of 50,000 μCi/sec at 30 minutes' decay for off-gas system of a BWR based on measured off-gas system noble gas release rates for operating BWRs, and (3) measurements of gaseous effluents for operating plants. For the reasons stated above, the second option specified in Table 12.1-1 in Chapter 12 of the Evolutionary Requirements Document and discussed above is acceptable. Further, the radiological consequences of liquid radioactive waste tank failures for an ALWR should be analyzed on the basis of reactor coolant concentrations of radioactive nuclides consistent with 0.12-percent failed fuel for a PWR and a noble gas release rate of 15 μCi/sec-MWt at 30 minutes' decay for the off-gas system for a BWR in accordance with SRP Section 15.7.3, "Postulated Radioactive Releases Due to Liquid-Containing Tank Failures."

The staff concludes that the second option for source terms recommended by EPRI for evaluating the expected performance of radioactive waste processing systems during normal plant operation including anticipated operational occurrences meets the applicable guidelines of SRP Sections 11.2 and 11.3. However, EPRI's source terms for the design of the radioactive waste processing systems specified in the Evolutionary Requirements Document in Table 12.1-1 are inconsistent with the guidelines of SRP Sections 11.2 and 11.3. Therefore, with regard to the design of radioactive waste processing systems, the staff will review individual applications for FDA/DC according to the criteria in SRP Sections 11.2 and 11.3. This DSER open issue is closed.

2.2.3 Releases of Radioactive Materials

Section 1.5.4 of Chapter 12 states that operation under the licensing evaluation conditions specified will result in gaseous and liquid radioactive effluent releases that are within the limits specified in 10 CFR Part 50, Appendix I, for normal conditions and within the limits specified in 10 CFR Part 20 for normal and accident conditions.

Section 2.2.3 of Chapter 12 requires that the effluent normally released to unrestricted areas meet the goals in Section 1.5.1 of Chapter 12.

2.2.4 Personnel Radiation Exposure

Section 2.2.4 of Chapter 12 specifies that the radioactive waste processing systems for the ALWR will be designed so that personnel radiation exposure from operation and maintenance of these systems is consistent with the station requirement of 100 person-rem/year. Since estimates of these personnel radiation exposures are plant specific, EPRI requires that the plant designers provide an estimate of expected personnel radiation exposures. The staff will evaluate the vendor's or applicant's estimate of personnel radiation exposure during its review of an individual application for FDA/DC.

Section 2.2.7 of Chapter 12 states that each unit at a site will have its own radioactive waste processing systems, which will be operated remotely from a central radwaste control room. Section 2.2.10 of Chapter 12 requires that measuring elements associated with radioactive waste system equipment having high radiation levels be located outside the equipment cubicles in lower radiation areas, where practicable, to minimize personnel exposures. These measuring elements should be static (with no moving parts) rather than dynamic devices, wherever possible, to reduce the potential for collection of radioactive crud. These features comply with the guidelines of Regulatory Guide 8.8, "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable," and are, therefore, acceptable.

Section 2.2.11 of Chapter 12 requires the plant designer to perform a robotics evaluation to identify applications of robotics to inspection, surveillance, and maintenance of the radioactive waste processing systems. In the rationale, EPRI states that inspection, surveillance, and maintenance activities associated with radioactive waste processing system operations have been significant contributors to overall plant personnel radiation exposures and that the use of robotics could reduce personnel exposures. In addition, the design features of the radioactive waste processing system will facilitate the use of robotics. The use of robotics to reduce the dose to plant personnel is in accordance with the guidance of Regulatory Guide 8.8 and is acceptable.

2.2.5 Operating Conditions/Availability

Section 2.2.5 of Chapter 12 requires that the gaseous, liquid, and solid radioactive waste processing systems be available for operation during all phases of plant operation. However, EPRI does not require the BWR gaseous waste processing system to be available for operation when the reactor is in the shutdown condition.

2.2.6 Process Systems Operating Capacity

Section 2.2.6 of Chapter 12 requires the radioactive waste processing systems to have adequate capacity to handle wastes resulting from all plant operating and shutdown modes as well as anticipated operational occurrences. The section also requires the radioactive waste processing system to accommodate infrequent, but usual, conditions and large waste volumes.

As previously noted, Section 1.5.9 of Chapter 12 requires that an onsite storage facility be provided that can hold wastes for a 6-month waiting period without solid radioactive waste shipments from the site.

2.2.7 Seismic Design and Quality Group Classification

Sections 2.2 and 2.2.9 of Chapter 12 require that radioactive waste processing systems and charcoal adsorber supports conform to the Quality Group C and D requirements and the codes, standards, and seismic provisions of Regulatory Guide 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," and that materials for pressure-retaining components also conform to the guidelines of this guide. In Section 4.6.3.3 of Chapter 6, EPRI requires that the radioactive waste building design and equipment structural supports meet the guidelines of Regulatory Guide 1.143.

2.2.8 Control and Instrumentation

Section 2.2.10 of Chapter 12 requires control and monitoring of the release of radioactive materials to the environment to be consistent with the requirements for the environmental monitoring system specified in Chapter 9 of the Evolutionary Requirements Document.

2.2.9 Process and Effluent Radiological Monitoring

In the DSER for Chapter 12, the staff concluded that Section 2.2.9 of Chapter 12 of the Evolutionary Requirements Document did not fully describe the requirements that are consistent with SRP Section 11.5, "Process and Effluent

Radiological Monitoring Instrumentation and Sampling Systems," for process and effluent radiological monitoring instrumentation and sampling, nor did it indicate EPRI's commitment to do so. This was identified as an open issue.

In its letter dated May 22, 1991, responding to the DSER. EPRI referred to Appendix B to Chapter 1, which contains a requirement that evolutionary ALWRs comply with the applicable SRP criteria with regard to process and effluent radiological monitoring. EPRI also provided a cross-index to the various chapters, sections, and tables in the Evolutionary Requirements Document for specific information on radiological monitoring and sampling provisions. EPRI further stated that it would revise the Evolutionary Requirements Document to include information on provisions for measuring steam generator blowdown effluent activity for an evolutionary PWR.

The staff has reviewed the referenced portions of the Evolutionary Requirements Document and concludes that although EPRI commits to comply with the criteria in SRP Section 11.5, the information in the Evolutionary Requirements Document does not support this commitment. EPRI has not provided details on the required monitoring and sampling provisions for a number of waste streams. For example, it is not clear if the ALWR design will include provisions to (1) grab sample and analyze the effluent from the plant stack for noble gases, iodines, particulates, and tritium activity; (2) grab sample the exhausts from auxiliary and radwaste buildings and the fuel storage area for iodine activity; and (3) grab sample the effluents from liquid radwaste, service water, laundry and decontamination waste, secondary coolant waste, and turbine building drain waste systems for tritium activity. Also, Chapter 12 has omitted some monitoring and sampling provisions identified in SRP Section 11.5, Tables 1 and 2, for the following waste streams:

- automatic control features for terminating effluents from the steam generator blowdown system for a PWR and from the waste gas holdup system for an ALWR

- continuous monitoring provisions for noble gas and iodine activity in the containment purge exhaust for an evolutionary PWR

- continuous monitoring provisions for noble gas activity and grab sampling provisions for iodine activity in the process stream from the condenser evacuation system

- grab sampling provisions for iodine activity in the mechanical vacuum pump and turbine gland seal exhausts for an ALWR and containment purge exhaust for a PWR

- grab sampling provisions for iodine activity in the process streams from the evaporator, pressurizer, pretreatment liquid radwaste tank, and turbine building vent systems (filtering the discharges from these vent systems by high-effluency particulate air filters and prefilters does not justify the omission of grab sampling provisions for iodine activity because these do not remove iodine in elemental and organic forms)

- continuous sampling provisions for service water system effluent activity

Chapter 1 of the Evolutionary Requirements Document contains EPRI's commitment to comply with the criteria in SRP Section 11.5. The staff expects that applicants referencing the Evolutionary Requirements Document will comply with the SRP, as committed to in Chapter 1, even though Chapter 12 does not adequately and explicitly address all associated design provisions for control, monitoring, and sampling of radioactive waste processing and effluent streams, as identified in the SRP. The staff will review individual applications for FDA/DC against the criteria in SRP Section 11.5, including monitoring and sampling provisions identified in Tables 1 and 2 of SRP Section 11.5. Therefore, this DSER open issue is closed.

2.2.10 Fire Protection

In a letter dated August 22, 1990, the staff noted that the Evolutionary Requirements Document did not contain fire protection requirements for the radioactive waste processing systems. In the DSER for Chapter 12, the staff concluded that a statement to provide fire protection for all radioactive waste processing systems should be included in Chapter 12 of the Evolutionary Requirements Document. In addition, specific fire protection considerations should be addressed in each section, as appropriate. This was identified as an open issue in the DSER.

EPRI's position is that all of the staff concerns related to fire protection for radioactive waste processing are addressed in other parts of the Evolutionary Requirements Document. Therefore, the information does not have to be repeated in Chapter 12. The staff reviewed the EPRI cross-references in Revision 1 of the Evolutionary Requirements Document. Those references, and the other EPRI commitments in its November 7, 1990, letter responding to the staff's August 22, 1990, letter, are summarized below:

Solid Radioactive Waste Processing

- Chapter 9, Section 3.2, addresses general requirements for fire protection (fire detection, fire suppression capabilities, and fire hazard analysis, etc.) and requires conformance to SRP Section 9.5.1, "Fire Protection Programs."
- Chapter 9 addresses the interface of the fire protection system with the heating, ventilating, and air conditioning system in Sections 8.2.1.1.4 (ventilation system penetrations), 8.2.1.1.17 (gas suppression), and 8.2.1.1.22 (charcoal filtration).
- Chapter 12, Section 5.4.2.8, specifically requires fire detection and suppression for radwaste storage facilities.

Liquid Radioactive Waste Processing

EPRI's response pertaining to solid radioactive waste processing also applies to liquid radioactive waste processing. In addition, EPRI included the following references specific to liquid radioactive waste processing:

- Chapter 1, Table 1.4-3, "Major Structural Design and Construction Codes," lists the national fire codes published by the National Fire Protection Association (NFPA). EPRI stated that this adequately addresses the issue of electrical equipment suitable for hazardous environments. EPRI stated, "specifically, NFPA 70, the National Fire Protection Code, is used for design classification and specification, and would apply to areas where, for example, the potential for oil vapor or hydrogen leakage is present (such as in offgas recombiner rooms)."

- In Chapter 12, Section 4.2.2.3.3 requires the exclusion of oily waste to the extent practicable; Section 4.3.5.1 prohibits the dry cleaning of protective clothing contaminated by radioactivity; and Section 4.3.6 (mixed waste) requires fire protection of stored mixed wastes (such as contaminated oil) that are flammable. It should be noted that the national fire code distinguishes between the words "combustible" and flammable" as they apply to liquids that will burn. The staff believes that EPRI inadvertently used the word "flammable" rather than the word "combustible." In any case, the staff approves the concepts outlined in Chapter 12, Section 4.3.6, of providing fire protection for combustible and flammable stored mixed wastes.

- Section 7.5.1.2 of Chapter 2 addresses the possibility of burning contaminated turbine lubricating oil in the plant auxiliary boiler.

Gaseous Radioactive Waste Processing

EPRI's responses pertaining to solid radioactive waste processing and liquid radioactive waste processing also apply to gaseous radioactive waste processing. In addition, EPRI included the following references specific to gaseous radioactive waste processing:

- Chapter 12, Section 3.3.4, requires continuous ventilation in all areas where flammable gases (primarily hydrogen) and/or radioactive gases may be present. The ventilation will provide a means of diluting and removing any flammable gases that may be present.

- Chapter 12, Section 3.2.3.2, addresses the requirements for maintaining waste gas streams free of flammable mixtures of hydrogen and oxygen. These requirements are necessary to protect the gaseous radioactive waste processing system itself from damage resulting from the possible explosion of a hydrogen-oxygen mixture and to protect charcoal adsorbers from becoming ignited. Chapter 12, Section 3.3.7.2.5, addresses detection and suppression of fires in BWR charcoal beds located downstream of hydrogen recombiners in the off-gas system.

EPRI referenced Chapters 9 and 12 in its response to staff questions concerning the disposal of fire suppressants that might become contaminated. EPRI stated that Chapter 9, Section 3.4.3.2, addresses the issue of fire suppressants becoming waste. However, this section only discusses fire water that is released during testing of fire suppression systems. EPRI also stated that Chapter 12, Section 4.3.3, discusses many aspects of the treatment of waste water collected by the floor drains throughout the plant. Neither of these references addresses fire water discharged during actual firefighting operations. However, the staff's interpretation of these statements is that EPRI intends to treat all discharged fire suppressants the same, whether discharged during system testing or during actual firefighting operations. On that basis, the staff concludes that this commitment by EPRI is acceptable.

The staff concludes that these references and commitments by EPRI are consistent with the enhanced fire protection criteria discussed by the staff in Chapter 9 of this report and are, therefore, acceptable. The DSER open issue regarding specific fire protection considerations being addressed in each section of the Evolutionary Requirements Document, as appropriate, is closed.

2.3 Conclusion

The staff concludes that the requirements in Section 2.2 of Chapter 12 of the Evolutionary Requirements Document do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional g'idance provided in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

3 GASEOUS RADIOACTIVE WASTE PROCESSING SYSTEMS

3.1 Functions

Section 3.1 of Chapter 12 of the Evolutionary Requirements Document states that a charcoal adsorber system for both BWRs and PWRs will be used for retaining fission gases for decay. Section 3.1.2 of Chapter 12 requires that the BWR and PWR charcoal adsorber systems be designed to perform the following functions:

- receive and/or collect radioactive waste gases that originate in the reactor coolant system and that require processing by holdup for decay before they are released
- maintain the system nonflammable
- condition the gases to provide the moisture and temperature conditions necessary for the desired performance of the charcoal adsorbers
- retain the off gases for the desired time for the decay of fission products (xenon and krypton radioisotopes) resulting from fuel leakage and tramp uranium on fuel surfaces
- transport the remaining gases to a monitored heating, ventilating, and air conditioning (HVAC) vent for monitoring and release to the atmosphere
- provide against inadvertent release of significant quantities of gaseous and particulate radioactive material to the environment by providing non-safety-related monitoring and alarm functions
- ensure that in-plant occupational exposures due to operation and maintenance of the off-gas systems are as low as is reasonably achievable (ALARA)

Section 3.1.2.2 of Chapter 12 states that the gaseous radioactive waste processing system for PWRs will not process the gases from the following systems, since they will contain radioactive gas only when there are concurrent fuel leaks and secondary steam generator tube leaks: main condenser air ejector, main condenser mechanical vacuum pump, turbine gland seal exhaust, and deaerator vent.

Section 3.1.2.3 of Chapter 12 requires that the BWR main condenser off-gas system be designed to perform the following functions:

- maintain hydrogen and oxygen mixtures noncombustible
- ensure that sufficient oxygen is present to react with the hydrogen added, if hydrogen water chemistry is used
- reduce the gas flow rate by the recombination of hydrogen and oxygen

- remove water vapor by condensation
- perform conditioning, decay, and transport functions

3.2 Performance Requirements

The following is a summary of some of the performance requirements for the BWR and PWR gaseous radioactive waste processing systems (GRWPSs) and other BWR systems (turbine gland seal steam off-gas system and mechanical vacuum pump off-gas system) identified in Section 3.2 of Chapter 12 of the Evolutionary Requirements Document. Additionally, the following summary includes some of the off-gas system and equipment requirements and the system control and instrumentation requirements for both BWRs and PWRs identified in Sections 3.3 and 3.4 of Chapter 12:

- Where the potential for an explosive mixture of hydrogen and oxygen exists, the system will be designed to maintain system integrity.
- For BWRs, the formation or buildup of explosive mixtures will be prevented, and the system will be designed to withstand the effects of a hydrogen detonation to permit operation to be resumed.
- For PWRs, parallel gas analyzers will be used to detect the formation or buildup of explosive mixtures, and the analyzers will annunciate locally and in the main control room for remedial action.
- The off-gas process stream will be continuously maintained nonflammable, that is, by maintaining hydrogen levels below 4 percent hydrogen by volume when oxygen is present (BWRs), or by maintaining oxygen levels below 4 percent by volume (PWRs).
- For BWRs, the hydrogen concentration will be maintained nonflammable by dilution with steam from the steam jet air ejector, and a dry air purge system will be provided upstream of each recombiner. The air purge flow rate and duration will be sufficient to purge any hydrogen from the system through the charcoal adsorbers.
- For PWRs, the gas in the system will be maintained slightly above atmospheric pressure.
- For PWRs, nitrogen will be available for inerting if the oxygen content of the gas stream exceeds 4 percent by volume.
- For BWRs, multiple charcoal adsorber beds will be arranged so that they can all be bypassed via a bypass bed.
- For PWRs, a minimum of two charcoal adsorber beds, in addition to a guard bed, will be provided with interconnections to bypass any one bed.
- Each BWR charcoal bed will be provided with a means for detecting and extinguishing a charcoal fire.
- Gases will be discharged to a monitored release point of the HVAC system.

- For BWRs, if radioactive steam is used for the turbine sealing steam, a 2-minute delay time will be provided in the off-gas pipe.

- For BWRs, turbine steam seal off gases and vacuum pump off gases will be transported to and exhausted at a monitored plant vent.

- GRWPS discharges to the plant vent will be monitored by a GRWPS process monitor and provided with a high-level radiation alarm. Final releases will be monitored by the HVAC monitor at the plant vent.

The following features will be provided by the GRWPS to be consistent with the guidelines in Regulatory Guide 8.8 for maintaining occupational exposures ALARA:

- Drain lines will be sized and continuously sloped to minimize the potential for plugging.

- Vents and drains will be designed to contain radioactive gases.

- Heat exchanger vent and drain valves either will be located in a low-radiation area or will be remotely operable.

3.3 Evaluation

3.3.1 Seal Steam

BWR designs have typically relied on the use of nonradioactive seal steam for turbine gland seals rather than the use of other seal steam to significantly reduce the release of radioactivity to the environment via the turbine gland seal exhausts. However, the original version of Chapter 12 of the Evolutionary Requirements Document did not fully describe the extent to which nonradioactive turbine seal steam for BWRs will be used, how the radioactivity levels in other seal steam used will be minimized, or how the 2-minute delay provided in the off-gas pipe will be effective in minimizing the radioactivity of the seal steam released through the plant vent. Therefore, this was identified as an open issue in the DSER for Chapter 12.

In its May 22, 1991, response to the DSER, EPRI recognized the rationale for using nonradioactive steam for BWR turbine gland seals. However, EPRI stated that using clean steam from a boiler will add to the plant condensate during startup, possibly create additional radwaste if condensate storage is full, and will create a need for a holdup delay pipe for gland seal system exhaust. Therefore, the twin objectives of minimizing radioactive releases from gland seal system exhaust and eliminating the creation of additional radwaste can be better achieved by providing a source that supplies essentially nonradioactive steam. EPRI indicated that such steam can be supplied by a re-boiler that is heated either by main steam or by auxiliary steam from an auxiliary boiler. EPRI further stated that the applicable sections of Chapters 2, 9, 12, and 13 of the Evolutionary Requirements Document would be revised to clarify the requirements for evolutionary BWRs to ensure that steam of sufficiently low radioactivity is used so that a 2-minute delay is unnecessary. The staff has reviewed the applicable sections of the chapters mentioned above and notes that, in particular, Section 3.2.4.4 of Chapter 13 contains the following requirement to control radioactive releases from the gland seal system:

Off-gas from the gland seal condenser (BWR) shall be monitored for radiation and shall be automatically routed to the gaseous radioactive waste processing system if radioactivity is detected. If the exhaust steam is normally radioactive, the off-gas shall be routed to the gaseous radioactive waste processing system.

The staff notes, however, that Figure 12.3-1 of the Evolutionary Requirements Document does not yet reflect this requirement. The staff assumes that Figure 12.3-1 is for illustrative purposes only and that EPRI intends that the requirements of Section 3.2.4.4 be met.

The staff concludes that EPRI's requirements in Chapter 13 and its justification for not using clean steam from an auxiliary boiler represent an acceptable approach and a design feature to address the turbine gland seal steam issue for an evolutionary BWR. Furthermore, EPRI has specified an acceptable requirement for providing an auxiliary steam system that, as one of its functions, will supply nonradioactive steam to turbine gland seals when main steam activity levels render it unsuitable for use as seal steam. Therefore, this DSER open issue is closed.

3.3.2 Heating, Ventilating, and Air Conditioning System Design

By letter dated March 22, 1989, the staff requested that EPRI provide additional information on how gaseous radioactive waste discharges from the GRWPS, BWR turbine seal off-gas system, and BWR mechanical vacuum pump off-gas system will be transferred to a plant vent through appropriate HVAC systems. In its response dated August 18, 1989, EPRI committed to specify in the Evolutionary Requirements Document the interfaces between the various gaseous radwaste systems and the HVAC systems through which the discharges will be transferred to the plant vent. The staff concluded that this was an acceptable commitment and identified the above item as a confirmatory issue in the DSER for Chapter 12.

Responding to the DSER confirmatory issue in a letter dated May 22, 1991, EPRI referred to Sections 3.2.5 and 3.4.2 of Chapter 12. Section 3.2.5 requires the plant designer to compile a list of vents from radioactive equipment throughout the plant that will enter the HVAC system. The list is to include the source (equipment or tank), the gas (normally air) flow rate, the radioactivity concentration, and the HVAC subsystem to which the vent will be connected. Additionally, the compilation is required to sum the air flows and radioactivities on a maximum and annual average basis. Section 3.4.2 requires the GRWPS to be monitored by a GRWPS process monitor with a high-level radiation alarm. The staff concludes that EPRI has provided requirements for the interfaces between the various gaseous radwaste systems and the HVAC systems through which the discharges are to be transferred to the plant vent. Therefore, this DSER confirmatory issue is closed. For BWRs, the staff expects that the plant designer's list will include information not only on the radioactive discharge from the GRWPS, but also discharges from other systems such as turbine gland seal and mechanical vacuum pump off-gas systems. The staff will review individual applications for FDA/DC for compliance with applicable regulations and regulatory guidance in this regard.

3.3.3 Installation of High-Efficiency Particulate Air Filters

In the original version of the Evolutionary Requirements Document, EPRI indicated that high-efficiency particulate air (HEPA) filters downstream of charcoal delay beds would be eliminated in the GRWPSs of ALWRs (Figure 12.3-1). Since current practice has been to include such downstream HEPA filters in the GRWPSs of LWRs, the staff requested by letter dated March 22, 1989, that EPRI provide additional information regarding the elimination. In its August 18, 1989, response to the staff's request, EPRI justified the elimination, stating that experience at operating plants has shown that an insignificant amount of radioactive material (i.e., particulates resulting from decay of noble gas radioisotopes when they are processed in the charcoal delay beds) collects at the downstream HEPA filters. However, EPRI did not give the details of this operating experience. Therefore, the staff identified the proposed elimination of the HEPA filter downstream of the charcoal delay beds of the GRWPS as an open issue in Section 3.3.3 of its DSER for Chapter 12. In a letter dated December 20, 1991, EPRI addressed the above concern by pointing out that the current practice is a holdover from past off-gas system designs that had only a 30-minute decay pipe before the stack. EPRI stated that current off-gas system designs include charcoal delay beds of several feet in diameter, and that flow rates in the system are low (typically 10 to 40 standard cubic feet per minute). Therefore, the flow velocities will be too low (much less than 1 foot per second) to transport significant amounts of radioactive particles of any size. By letter dated December 20, 1991, EPRI reported the results of its industry survey, which confirmed the rationale for eliminating the downstream HEPA filters in the GRWPS. In its submittal, EPRI concluded that its rationale for eliminating the downstream HEPA filters is equally valid for the PWR GRWPSs that use charcoal holdup of noble gases. On the basis of its review of the above submittal, the staff agrees with EPRI's position. Therefore, the DSER open issue is resolved.

With regard to gaseous effluents from ventilation exhaust systems during normal plant operation including anticipated operational occurrences, compliance with 10 CFR Part 50, Appendix I offsite dose limit objectives for these effluents may require charcoal adsorbers and/or HEPA filters in the exhaust systems to reduce the release of radioiodine in elemental and organic forms and radioactive particulates to the environs. For a ventilation exhaust system for which a filtration system is needed that includes both the charcoal adsorber and the HEPA filter, the staff allows the filter efficiencies specified in Regulatory Guide (RG) 1.140 (the applicable guide for normal ventilation exhaust filtration systems) for the removal of radioiodine and radioactive particulate from the effluent stream only if the filtration system, as stated in SRP Section 11.3, is designed, tested, and maintained in accordance with the RG 1.140 guidelines. The guide, in turn, states that HEPA filters should be provided, one upstream of the charcoal adsorber and another downstream of the adsorber; the purpose of the downstream one is to collect carbon fines. The staff considers that it is incorrect to assume the regulatory guide efficiencies for the removal of elemental and organic iodine from a ventilation exhaust if there is no HEPA filter downstream of the charcoal adsorber for collecting potential carbon fines. Therefore, in Section 3.3.3 of the DSER for Chapter 12, the staff requested that EPRI clarify how the elimination of a downstream HEPA filter and supporting rationale apply to air filtration and adsorption units installed in normal ventilation exhaust systems and identified this as an open issue. In its response dated May 22, 1991, EPRI referred to Chapter 9 of the Evolutionary Requirements Document, Section 8.2.1.1.22, which requires compliance with 10 CFR Part 50, Appendix I. The staff has reviewed the subject section and finds it requires a post-filter instead of a HEPA filter downstream of the adsorber to collect carbon fines and then only if the discharge is to other safety-related equipment or occupied spaces. The staff believes that a simple post-filter will not be as effective as a HEPA filter in collecting carbon fines. Therefore, it concludes that EPRI has not justified its position for assuming the efficiencies specified in the regulatory guide for the removal of elemental and organic iodine from the effluent stream if there is no HEPA filter downstream of the charcoal adsorber for collecting carbon fines, as specified in the SRP. The staff will review individual applications for FDA/DC against the SRP criteria. Therefore, this DSER open issue is closed.

3.3.4 Hydrogen Control

Chapter 12 of the Evolutionary Requirements Document specifies design criteria that are intended to prevent the formation of explosive hydrogen and air mixtures and to ensure that the GRWPS is designed to withstand the effects of detonations. EPRI states that the off-gas process stream will be continuously maintained nonflammable by limiting the hydrogen volumetric concentration to less than 4 percent. In BWRs, this is accomplished by dilution with the steam from the steam jet air ejector. In the case of hydrogen water chemistry, when waste gases contain an excess of hydrogen, stoichiometric amounts of oxygen will be injected upstream of the recombiner. In PWRs, where the off-gases are infrequently received from the reactor coolant and auxiliary building drain tanks and where the boron recycle system is the only plant degasifier providing waste gas to the GRPWS, gas analyzers connected to the annunciators will be provided to warn the operators and let them take remedial actions. Also, oxygen concentration in the off-gas will be maintained below 4 percent by volume.

Item II B.6 of SRP Section 11.3 gives the features required to protect the GRWPS from potentially explosive mixtures of hydrogen and oxygen. In a letter dated March 22, 1981, the staff requested that EPRI give its position on compliance with this criterion. In its response dated August 18, 1989, EPRI committed to revise the Evolutionary Requirements Document to make the design of the GRWPS consistent with the SRP acceptance criterion. The staff concluded that this was an acceptable commitment and identified it as a confirmatory issue in the DSER for Chapter 12.

In response to the DSER confirmatory issue, EPRI has revised Table B.1-2 of Appendix B to Chapter 1 to show that the ALWR will be designed to comply with SRP Section 11.3. However, the requirements in Section 3.2.3 of Chapter 12 are not sufficiently detailed to enable the staff to conclude that the GRWPS will be designed to be consistent with the SRP acceptance criterion. For example, the section does not state the criterion for minimum design pressure of the GRWPS for a BWR to withstand the effects of a hydrogen explosion, nor does it provide the needed number, type, and location of analyzers for monitoring hydrogen and oxygen. Also, Table 12.3-1 of Chapter 12 does not provide sufficient details to conclude that the monitoring provisions will be consistent with the SRP acceptance criterion.

Although Chapter 12 of the Evolutionary Requirements Document does not address all the criteria in the SRP, Chapter 1 requires that vendors comply with SRP Section 11.3. The staff expects that applicants referencing the Evolutionary

Requirements Document will comply with the SRP, as committed to in Appendix B to Chapter 1, and concludes that this is acceptable. The staff will review individual applications for FDA/DC against the SRP criteria discussed above. Therefore, this DSER confirmatory issue is closed.

3.3.5 Bypass of Charcoal Beds

The original version of Chapter 12 of the Evolutionary Requirements Document stated that for the PWR GRWPS, charcoal beds would be provided with interconnections to bypass any beds.

In its August 18, 1989, response to the staff's request for information dated March 22, 1989, on bypass provisions as they relate to the design of the charcoal adsorber beds for PWRs, EPRI committed to change the design to allow the bypassing of any one bed (EPRI requires the PWRs to have one guard bed and at least two charcoal adsorber beds). The staff concluded that this was acceptable and identified the commitment to revise the Evolutionary Requirements Document as a confirmatory issue in the DSER for Chapter 12.

In a letter dated May 22, 1991, EPRI stated that it had revised Section 3.3.2.3 of Chapter 12 to allow the bypassing of any one charcoal adsorber bed. The staff has verified that this revisions has been made. Therefore, this DSER confirmatory issue is closed.

3.3.6 Fire Protection

In the DSER for Chapter 12, the staff identified fire protection requirements for the GRWPS as an open issue. The staff discusses in detail the closure of this issue in Section 2.2.10 of this chapter. Therefore, this DSER open issue is closed.

3.4 Conclusion

The staff concludes that the requirements of Section 3 of Chapter 12 of the Evolutionary Requirements Document do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

4 LIQUID RADIOACTIVE WASTE PROCESSING SYSTEM

4.1 Functions

Section 4.1.2 of Chapter 12 of the Evolutionary Requirements Document requires that the liquid radioactive waste processing system (LRWPS) be designed to perform the following functions:

- Classify and segregate wastes into subsystems for collection and efficient and economical processing.

- Provide the capacity to accumulate and process liquid radioactive wastes produced in the plant during normal operation and during anticipated operational occurrences, including shutdown, refueling, and maintenance, without affecting plant availability.

- Provide alternative or redundant processing paths to ensure LRWPS and plant availability. This includes provisions for the use of mobile equipment.

- Provide for the transfer of filter backwashes, tank sludge, and spent resin to the solid radioactive waste processing system.

- Produce treated waste of acceptable quality for reuse within the plant, as appropriate, particularly that from BWR equipment drains.

- Produce treated effluents that can be discharged to the environment within the ALWR goals. The staff discusses these ALWR goals in Section 2.1 of this Chapter.

- Control and monitor LRWPS releases of chemical and radioactive materials to the environment in accordance with the applicable regulatory requirements.

- Protect plant personnel from radiation exposure and incorporate the basic ALARA (as low as is reasonably achievable) objectives by, for example, the use of automated systems, appropriate arrangement, reliable and readily operable and maintainable equipment, shielding, and remotely operated instrumentation and controls.

4.2 Performance Requirements

The following is a summary of some of the performance, arrangement, and equipment requirements for the LRWPS given in Sections 4.2, 4.4, and 4.5 of Chapter 12 of the Evolutionary Requirements Document:

- Radioactive wastes will be segregated according to the following subsystems: equipment drains, floor drains, chemical wastes, and detergent wastes, and mixed wastes.

- There will be a single monitored pipe from the LRWPS sample tanks to a routing to the environment.

- A minimum flow of dilution water for radioactive waste discharges will always be available.

- All liquid radioactive waste will be discharged to the environment via tanks where the contents of the tanks will be mixed and sampled and proven acceptable before they are discharged.

- Each subsystem of the LRWPS will have sufficient process flow and storage capacity to process the inputs during normal operation and during anticipated operational occurrences.

- Provision will be made for the collection of leakage and spills and for the control of radioactive gases and particles in locations where mobile equipment may be used.

- Tanks will be designed to prevent uncontrolled release of radioactive material due to spillage.

- Hydrogen-containing wastes in PWRs will be collected in covered drain tanks or routed directly via the chemical and volume control systems to the borated waste processing subsystem.

- To eliminate a potential source of airborne radioactivity, liquid radioactive wastes from non-hydrogen-bearing (PWR) radioactive or potentially radioactive plant systems will be piped directly from radioactive plant systems to sumps or collection tanks.

- Equipment drain sumps in controlled access areas will be provided with curbs to prevent them from becoming contaminated in the event of flooding from ad_ ent floors.

- Floor drain piping will be routed and/or sealed to prevent cross flow of airborne radioactivity between building rooms and/or compartments where such cross flow is undesirable.

- Piping for concentrated chemical solutions will be sized to prevent plugging during resin transfer and will have provisions for flushing to keep it free of solids after use; the piping will be designed to preclude solidification of the solution in the lines and heat traced, as appropriate.

- Valves used in the LRWPS must not act as crud traps. Materials used for valve packing will have adequate radiation resistance to minimize the need for replacing the packing.

- Pumps will be flange-connected to facilitate pump removal and replacement.

- Evaporators (when used) will be designed for ease of disassembly and assembly and replacement of internal components. Also, they will be capable of remote operation during maintenance activities.

- Remote or semi-remote handling techniques and equipment will be used to the extent practicable in the operation and maintenance of the system.

- All tanks will be provided with outside ladders and manholes sized to permit easy access for personnel wearing anticontamination clothing. To minimize the accumulation of crud on tank bottoms (and the ensuing increase in radiation levels), tank bottoms will be sloped or dished with a drain line at the lowest point of the tank and crevices and crud traps will be excluded during fabrication.

- Evaporators will be capable of being drained and flushed after use to prevent crud buildup and will be provided with connections for chemical decontamination. Radioactive components of the evaporator complex will be arranged in separate shielded areas to reduce radiation exposure from adjacent components during maintenance activities.

- Valves and instrumentation in lines servicing the evaporator will be located outside the evaporator enclosure so that maintenance on or operation of these components can be performed in a lower radiation field. In addition, all evaporator sampling points will be shielded to minimize personnel exposure.

In the original version of the Evolutionary Requirements Document, EPRI implied that the requirement for direct piping of liquid radioactive waste from radioactive plant systems to sumps or liquid radioactive waste collection tanks to eliminate potential sources of airborne radioactivity in the plant was equally applicable for BWRs. Additionally, if included the following information:

- LRWPS filters - functional requirements; requirements for backwashing (if applicable) and pressure drop and pressure capability of internal components; requirements or guidance for specific filter types: cartridge type, pressure precoat (vertical tube and centrifugal discharge) types, etched disk type, and crossflow type; requirements for filter housing and internal components

- ion exchangers - design considerations and operational requirements (e.g., resin addition and removal; resin retention; strainers; underdrains; and disassembly, assembly, and replacement of internal components)

EPRI deleted the above information in Revision 3 of the Evolutionary Requirements Document. During its reviews of individual applications for FDA/DC, the staff will review the design and operating procedures for filters and ion exchangers and the piping layout for transporting liquid radioactive wastes from applicable plant systems to liquid radioactive waste collection tanks or sumps to determine whether these features facilitate ease of plant operation, minimize unscheduled plant shutdowns, and are consistent with keeping occupational exposures ALARA.

4.3 Conclusion

The staff concludes that the requirements of Section 4 of Chapter 12 do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

5 SOLID RADIOACTIVE WASTE PROCESSING SYSTEM

5.1 Definition

The solid radioactive waste processing system will include the wet solid waste processing system, the dry solid waste processing system, and the onsite storage facility. According to the Evolutionary Requirements Document, wet solid wastes will consist of spent resins, filter backwash sludges, and tank sludges. Dry solid wastes will consist of compactible wastes, such as rags, paper, and clothing, and of noncompactible wastes, such as contaminated tools, discarded radioactive equipment parts, maintenance wastes, and PWR filter cartridges.

5.2 Wet Solid Waste Processing System

5.2.1 Functions

Section 5.2.1 of Chapter 12 of the Evolutionary Requirements Document requires that the wet solid waste processing system be designed to perform the following functions:

- Transport, receive, store, and process sludges from filter backwash and tank settling, and resins from ion exchangers. Processing will include sludge concentration in phase separators, with routing of the decant to the liquid radioactive waste processing system.
- Transfer the spent resins and sludges and dewater them within a shipping container.
- Return removed fluids to the liquid radioactive waste processing system.
- Cap or otherwise seal the container.
- Sample the waste in a representative location to determine its classification in accordance with 10 CFR Part 61.
- Sample the external surface of containers (or shield for shielded containers) for surface contamination.
- Transport filled containers to the onsite storage facility if shipment is temporarily not possible.

5.2.2 System Requirements

The following is a summary of some of the performance, system, and equipment requirements for the wet solid waste processing system described in Sections 5.2.2 and 5.2.3 of Chapter 12:

- Spent ion exchange resins will be collected by type (bead or powder) and/or by expected radiation level in either spent resin or phase separator tanks.

- The waste sludge phase separator tank will collect filtered backwash sludges, collector tank sludges, and concentrates from BWR condensate polisher prefilters.

- In the BWR, the reactor water cleanup (RWCU) filter/demineralizer resins and the fuel pool filter/demineralizer resins will be collected in two parallel RWCU phase separator tanks.

- The plant designer will establish the dewatering system capacity and process schedule to enable a tank of wet wastes to be processed and shipped within one-half the time interval between successive discharges into the spent resin tank or phase separator tank.

- The wet solid waste processing system will be capable of producing a product that satisfies the waste characteristics requirements of 10 CFR 61.56, pertinent State regulations, and disposal site requirements.

- The plant designer will define the set of process operating parameters and associated tolerances that ensure that the waste characteristics requirements can be met for each type of wet solid waste processed.

- The plant designer will define a test program that demonstrates that the waste characteristics requirements can be met for each type of wet solid waste to be processed. Testing is required for new process equipment or different waste forms. If the process equipment and waste types are identical to those at operating plants, the designer may substitute the results of operating experience for performance testing.

- The plant designer will design the dewatering equipment, as well as the permanent piping and valves, for receipt of spent resins and sludges and return of process effluents and will provide the interface and performance requirements for the use of mobile equipment for the dewatering of resins and sludges, if desired.

- Means will be provided to permit future transfer of spent resins and sludges to an in-plant solidification facility.

- Piping used for the hydraulic transport of slurries, such as ion exchange resins, filter backwash sludges, and waste tank sludges, and of waste concentrates (if present) will be sized to prevent plugging during transport and will have provisions for flushing.

- Means will be provided to permit a radiation survey of the contents of each waste container so that the waste can be classified in accordance with 10 CFR 61.55. Radiation surveys of container contents will be performed by using gamma scans from outside the container, if possible, rather than by monitoring waste removed from the container.

- Means will be provided to obtain samples periodically for determining and verifying the scaling factors used for waste classification.

- The design of the equipment for dewatering the radioactive slurry will incorporate features such as the capability to hook up and disengage the filling head to the container either remote automatically or remote manually to minimize operator exposure. Additionally, the design will permit the above operations to be performed manually. The slurry container will be designed to prevent slurry overflow and will be vented to minimize the spread of airborne contamination.

- Filled containers will be properly shielded, as needed; filled containers that are not shielded will be remotely transported to minimize operator radiation exposure.

The expected isotopic distribution and resulting radiation levels to be used for shielding evaluations of systems containing wet solid wastes are not within the scope of the Evolutionary Requirements Document and will be defined by the plant designer.

5.3 Dry Solid Waste Processing System

5.3.1 Functions

Section 5.3.1 of Chapter 12 of the Evolutionary Requirements Document requires that the dry solid waste processing system be designed to perform the following functions:

- segregate wastes at the source locations
- transport dry solid wastes to the radioactive waste facility
- provide interim storage for incoming dry solid wastes
- sort dry solid waste (compactible from noncompactible, waste with activity too high for hand sorting, nonradioactive waste, and waste that will be reused)
- compact dry solid waste that is compactible
- package both compactible and noncompactible dry solid waste into storage or shipping containers
- transport filled containers to the shipping vehicle or the onsite storage facility
- monitor the waste to determine its classification in accordance with 10 CFR Part 61.

5.3.2 System Requirements

The following is a summary of some of the performance, system, and equipment requirements for the dry solid waste processing system given in Sections 5.3.2 and 5.3.3 of Chapter 12:

- The dry solid waste processing system will be capable of producing a product that satisfies the waste characteristics requirements of 10 CFR 61.56, pertinent State regulations, and disposal site requirements.

- Means will be provided to permit the monitoring of dry solid waste containers to determine the classification of the waste in accordance with 10 CFR 61.55.

The following requirements comply with Regulatory Guide 8.8:

- Unsorted dry solid waste will be stored in a separate room with one area for high-activity waste and another for low-activity waste. Movable shielding will be provided to separate the high- and low-activity waste storage areas.

- Equipment needed for transporting filled waste shipping containers will be shielded to minimize operator exposure.

- Both the sorting table (the table for sorting dry solid wastes by hand) and the compactor for dry solid waste will have dedicated air filtration systems with high-efficiency particulate air filters to prevent the spread of airborne contamination and to limit respirator use by personnel, as appropriate.

5.4 Onsite Storage Facility

5.4.1 Functions

Section 5.4.1 of Chapter 12 of the Evolutionary Requirements Document requires that the onsite storage facility be designed to perform the following functions:

- Provide for at least 6 months of storage of all packaged wet and dry solid wastes.

- Provide shielding as required.

- Provide for transport, placement, and removal of packaged wastes within the premises.

- Provide means for collecting spilled liquids and releasing airborne radioactivity via monitored release paths.

- Provide shielded space for radioactive decay of packaged wastes before they are shipped. This is included in the 6-month space requirement.

5.4.2 Performance Requirements

The following is a summary of some of the performance requirements for the onsite storage facility identified in Section 5.4.2 of Chapter 12:

- High- and low-radiation waste containers will be stored in separate shielded storage areas within an onsite storage facility that will be in close proximity to the radioactive waste facility and within a common low-level, controlled access area. The storage areas will be shielded so that radiation exposure from the stored containers will not restrict access to onsite areas outside the storage area and will not exceed 2.5 mrem/hour for adjacent areas.

- The storage facility will have curbs to contain any [illegible] of solids or liquids (e.g., sludges or dewatered resins) res[illegible] the inadvertent breach of a waste container, and the buil[illegible]e will be vented through the heating, ventilation, and [illegible]g system to prevent the uncontrolled release of any airb[illegible]ity.

- The high-radiation storage area will be provi[illegible] remote viewing capability to verify handling operations and t[illegible]t identification of the containers.

- The required storage volume will be based on the maximum number of full shipping or storage containers used in 6 months and the number of containers required to fill one transport vehicle, plus a 25-percent margin.

- The storage area will be located indoors.

- The facility will have provisions for collecting any spilled radioactive liquids and returning them to the liquid radioactive waste processing system.

5.5 Conclusion

Chapter 12 of the Evolutionary Requirements Document does not include the design of shipping containers as part of the requirements for the solid radioactive waste processing system. However, with regard to shipping containers for the processed wet solid wastes, EPRI has identified an interface requirement for the plant designer in Section 5.2.1.4 of Chapter 12. This interface requirement requires the plant designer to interface with the shipping container supplier and with disposal sites to ensure compatibility with system designs. Therefore, the staff concludes that the design of the shipping container is not within the scope of the Evolutionary Requirements Document. Although the Evolutionary Requirements Document does not include an explicit interface requirement for the shipping container for processed dry solid wastes, the staff concludes that the design of dry waste shipping containers also is not within the scope of the Evolutionary Requirements Document. For the above reasons, the staff will review the design of shipping containers both for wet and dry solid wastes against the acceptance criteria in SRP Section 11.4, "Solid Waste Management Systems," and applicable sections of 10 CFR Part 61 during its review of individual applications for FDA/DC.

The staff concludes that the requirements of Section 5 of Chapter 12 of the Evolutionary Requirements Document do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information to make a determination that the plant-specific design and arrangement will be adequate. Therefore, applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance provided in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

6 CONCLUSION

The staff concludes that the EPRI requirements established in Chapter 12 of the Evolutionary Requirements Document for the design and arrangement of the radioactive waste processing systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the staff to determine if the plant-specific design and arrangement of the radioactive waste processing systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the SRP, or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 12 specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose radioactive waste processing systems are such that there will be no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A to Chapter 12 of the Evolutionary Requirements Document contains a list of acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

APPENDIX B
SUMMARY OF DESIGN AND OPERATING TECHNIQUES TO REDUCE RADIOACTIVE WASTE

Appendix B to Chapter 12 of the Evolutionary Requirements Document provides a summary of design and operating techniques to reduce the generation of liquid, solid, and gaseous radioactive waste volumes; minimize liquid waste contamination; minimize area contamination; ease cleanup of contaminated areas; and provide equipment decontamination capability. Additionally, this appendix summarizes EPRI's perception of good management and operating practices for meeting the objectives mentioned above. A few examples of the techniques are the following:

(1) Use demineralizers instead of evaporators for processing liquid radioactive waste.

(2) Use precoat filters with body feed and organic polymers in the liquid radioactive waste processing system.

(3) Discard resins (e.g., BWR condensate polisher resins; deep bed resins in radioactive waste ion exchangers, the spent fuel pool cleanup system, and the PWR chemical and volume control system) after their full use rather than regenerate them.

(4) Provide hydraulic equipment with the means for retaining and collecting oil to prevent the oil from escaping to floors and floor drains.

(5) Dewater wet solid wastes rather than solidify them to avoid an increase in waste volume because of solidification additives and the flushing or cleaning of solidification equipment.

(6) Provide hollow fiber filters upstream of condensate polishers to avoid cleaning the polisher resin.

(7) Use ambient temperature charcoal delay beds to reduce vulnerability to charcoal contamination from malfunction of gas conditioning equipment.

(8) Eliminate high-efficient particulate air exhaust filters in the gaseous radioactive waste processing system (GRWPS).

(9) Use volume-reduction technologies, such as incineration and supercompaction, for still further reductions in the volume of processed solid wastes.

The staff concludes that the appendix contains guidelines that may be useful to the plant designer (for meeting the objectives outlined above) except the incineration technique recommended in Item 9. The recommendation is contrary to EPRI's statement in Section 1.5.6.3 of Chapter 12. This section rules out the use of incineration for reducing solid waste volume because incinerator systems are complicated, present added licensing requirements, and may be counter to EPRI's ALWR "good neighbor policy." EPRI has included the appendix for information only and does not consider it part of the Chapter 12 requirements (Chapter 12, Section 1.2). Therefore, the staff considers all the design and operating techniques identified in the appendix as suggestions or recommendations for the plant designer, except for a few, which are identified as requirements in other parts of Chapter 12 (e.g., Item 8, elimination of HEPA exhaust filters downstream of charcoal delay beds in the GRWPS, is indicated in Figure 12.3-1). The staff has no position on the recommendations that are not identified as requirements elsewhere in the Evolutionary Requirements Document.

CHAPTER 13, "MAIN TURBINE-GENERATOR SYSTEMS"

1 INTRODUCTION

This chapter of the SER documents the NRC staff's review of Chapter 13, "Main Turbine-Generator Systems," of the Evolutionary Requirements Document through Revision 3. Chapter 13 was prepared, under the project direction of EPRI and the ALWR Utility Steering Committee, by Duke Power Company; General Electric Company; MPR Associates, Inc.; S. Levy Inc.; Science Applications International Corporation; Westinghouse Electric Corporation; and EPRI.

On February 6, 1989, EPRI submitted the original version of Chapter 13 of the Evolutionary Requirements Document for staff review. By letters dated March 22, September 14, and October 19, 1989, and July 13, 1990, the staff requested that EPRI supply additional information. EPRI provided the information in its responses dated August 18 and December 22, 1989, and January 18, March 16, and October 12, 1990.

On January 15, 1991, the staff issued its DSER for Chapter 13 of the Evolutionary Requirements Document. On May 29, 1990, the staff and EPRI met with the Advisory Committee on Reactor Safeguards Subcommittee on Improved Light Water Reactors to discuss Chapter 13, the staff's corresponding DSER, the outstanding issues from the staff's review of Chapter 13, and EPRI's approach to resolving each issue.

On September 7, 1990, EPRI submitted Revision 1 of the Evolutionary Requirements Document. Revisions 2, 3, and 4 were docketed on April 26 and November 15, 1991, and April 17, 1992, respectively.

1.1 Review Criteria

Section 1 of Volume 1 of this report describes the approach and review criteria used by the staff during its review of Chapter 13 of the Evolutionary Requirements Document.

1.2 Scope and Structure of Chapter 13

Chapter 13 of the Evolutionary Requirements Document defines the ALWR Utility Steering Committee's overall requirements for the main turbine-generator systems including the main turbine system, the main generator system, and the support subsystems for each. Although these requirements apply to BWRs and PWRs, which will be rated up to 1350 MWe, a plant rated at 1100 MWe with a six-flow turbine was used in establishing some requirements that are based, in part, on economic evaluations.

The key topics addressed in the Chapter 13 review include EPRI-proposed design requirements for

- availability
- planned outage schedule

- duty cycle
- abnormal operating conditions
- equipment environment

1.3 Policy Issues

During its review of Chapter 13 of the Evolutionary Requirements Document, the staff did not identify issues that involve policy questions for the technical areas discussed in this chapter, other than those already identified in the Commission papers listed in Appendix B to Chapter 1 of this report.

1.4 Outstanding Issues

The DSER for Chapter 13 of the Evolutionary Requirements Document contained the following outstanding issues:

Open Issues

(1) 60-year design life (2.2)

(2) foundation design for turbine-generator systems (2.3)

(3) seismic design of BWR main steamline (3.1.1)

(4) dynamic seismic system analysis for seismic Category II BWR components or systems (3.1.1)

(5) seismic design of BWR turbine stop valves (3.1.1)

(6) inspection and quality assurance guidelines for turbine stop valves, turbine control valves, turbine bypass valves, and main steam leads (3.1.2)

(7) testing and inspection techniques for main turbine (3.1.2)

(8) turbine maintenance program (3.1.3)

(9) probability of turbine missile generation (3.1.4)

(10) post-machining inspection of one-piece rotor (3.1.5)

(11) performance requirement for turbine exhaust boots (3.1.7)

(12) nozzle block alignment (3.1.8)

(13) radial and thrust bearing performance (3.2)

(14) overspeed limit for governor (3.3)

(15) load shedding without turbine trip (3.3)

(16) screens in reheat stop or intercept valves (3.3)

(17) inservice inspection of main stop and control valves and reheat stop and intercept valves (3.3)

(18) extraction steam check valves (3.3)

(19) detection of hydrogen seal oil leakage (4.5)

(20) generator instrumentation (4.8)

Confirmatory Issues

None

The final disposition of each of these issues is discussed in detail in the appropriate section of this chapter, as indicated by the parenthetical notation following each issue. All outstanding issues identified in the DSER for Chapter 13 of the Evolutionary Requirements Document have been resolved.

1.5 Vendor- or Utility-Specific Items

The vendor- or utility-specific items, with references to appropriate sections of this chapter given in parentheses, are listed below. The designators in front of each issue provide a unique identifier for each issue. The letter "E" indicates that the issue applies to evolutionary plant designs. The first number designates the chapter in which it is identified. The letter "V" designates that it is a vendor- or utility-specific item. The final number is the sequential number assigned to it in the chapter.

E.13.V-1 60-year design life for major components of the main turbine-generator (2.2)

E.13.V-2 use of seismic experience data base for seismic qualification (3.1.1)

E.13.V-3 performance and safety requirements for main turbine (3.1.3)

E.13.V-4 turbine maintenance program

E.13.V-5 effect of other duty cycles on long-term integrity of the turbine (3.1.4)

E.13.V-6 facture toughness properties of turbine casing material (3.1.4)

E.13.V-7 part-machining inspection of one-piece rotor (3.1.5)

E.13.V-8 need for prototype testing of new or significantly changed designs (3.1.6 and 4.1.1)

E.13.V-9 adequacy of turbine control system (3.3)

E.13.V-10 inservice inspection intervals for main stop and control valves and reheat stop and intercept valves (3.3)

E.13.V-11 seal clearances of gland seal system (3.4)

2 POLICY STATEMENTS AND KEY REQUIREMENTS

2.1 Policy Statements

Chapter 13 of the Evolutionary Requirements Document specifies requirements for the turbine-generator systems that are applicable to evolutionary LWRs. Section 1 of Chapter 13 contains those policies established by the ALWR Utility Steering Committee relating to the design approach to be used in developing the main turbine system and the main generator system. The main turbine system will include the main turbine, the lube oil system, the turbine control system, the gland seal system, and instrumentation. The main generator system will include the main generator, the excitation system, the stator cooling water system, the hydrogen cooling system, the hydrogen seal oil system, the hydrogen and carbon dioxide system, the generator control system, and instrumentation.

Section 1.5 of Chapter 13 specifies key requirements regarding design life, operability (normal and abnormal conditions), reliability, accessibility, maintainability, and inspectability for evolutionary LWRs for which the Evolutionary Requirements Document is applicable.

2.2 Performance and Operational Requirements

Section 2.2.1 of Chapter 13 of the Evolutionary Requirements Document states that the turbine-generator will be designed to operate for 60 years without an extended refurbishment outage being necessary. The turbine-generator designer will identify specific actions to improve turbine-generator availability to meet the goal for overall plant average annual availability specified in Chapter 1 of the Evolutionary Requirements Document. The planned outage for the ALWR turbine-generator will be concurrent with refueling outages. Overall requirements specify that regular annual planned maintenance will be completed within an average of 25 days or less (see Section 2 of Chapter 1 of the Evolutionary Requirements Document). An additional 180 days of outage will be allowed in a 10-year period. The turbine-generator and turbine valves should be capable of operating for a minimum of 6 years between inspections. EPRI states that current good practices indicate 10-week outages every 5 to 6 operational years are appropriate for a major turbine-generator inspection.

Section 2.2.1 of the Requirements Document states that the vendor of the turbine-generator will identify major components that will require replacement in less than 60 years. By letter dated July 13, 1990, the staff requested justification for the specific time period for the main turbine-generator systems. In addition, it requested that EPRI address how it determines overall design life. This was identified as an open issue in the DSER for Chapter 13. By letter dated October 12, 1990, EPRI stated that changes to Chapter 13 in the Evolutionary Requirements Document had been made to address this concern. The staff finds that Section 2.2.1 has been revised to add a statement that the estimate and basis of the expected life of these components will be identified. Furthermore, Section 3.3 of Chapter 1 of the Evolutionary Requirements Document states that the ALWR plant will be designed for 60 years of operation without the need for an extended refurbishment outage and to permit expeditious component replacement because of obsolescence and failure over a lifetime of 60 years. The staff concludes that EPRI's requirements in Section 2.2.1 that the turbine-generator be designed to operate for 60 years or be designed to facilitate replacement do not conflict with regulatory requirements for non-safety related systems. Therefore, this DSER open issue is closed. However, the overall design life will have to be qualified as discussed in Chapter 1 of this report. The staff will evaluate this issue during its review of an individual application for FDA/DC.

Because several large U.S. utilities may have a substantial portion of their load served by nuclear power, some load-cycling service may be desirable. Accordingly, a load-follow operating cycle is specified in Section 2.2.4 of Chapter 13 of the Evolutionary Requirements Document.

Section 2.2.4.2 of Chapter 13 states that the capability to supply in-house loads for 2 hours in the event of a loss of offsite power without any detrimental effect on the systems or components will significantly reduce the frequency of a core damage accident.

Section 2.2.5 of Chapter 13 states that adequate design margin will be provided to permit off-normal frequency operation without damage for periods of time that are long enough to permit initiation of protective trips and to recover without trip for short-duration frequency deviations. EPRI also states that the design of the turbine-generator and components will provide sufficient margin and/or redundancies to account for anticipated abnormal operating conditions to avoid limiting conditions of operation over the entire operating cycle.

2.3 System and Equipment Requirements

Section 2.3.1 of Chapter 13 of the Evolutionary Requirements Document states that the use of proven technology is fundamental to the concept of the ALWR. However, EPRI establishes no specific criteria for the number of years required before a design will be considered to be proven. EPRI states that improvements in the design of components of proven experience may be made for ALWRs for which the Evolutionary Requirements Document is applicable without resulting in changes to the basic configuration of the component.

There are no code requirements that are specifically applicable to the analysis of most of the major turbine-generator components. Therefore, the Evolutionary Requirements Document establishes minimum criteria for the analysis of turbine-generator components in the areas of stress, brittle fracture, fatigue, and flaw size.

Additional requirements for the turbine-generator system are provided in Section 2.3 of Chapter 13 in the areas of analysis of the structural foundation; operability and maintainability; equipment access; maintenance, inspection, and testing requirements; modularization; and fire protection.

In a letter dated July 13, 1990, the staff requested that EPRI address allowable soil (static and dynamic) characteristics and parameters considered for the design of the foundations of the main turbine-generator systems. In addition, EPRI was asked to address applicable structural design parameters, static and dynamic models to be used in the systems analysis, loading assumptions, and other characteristics for the foundation design of the turbine-generator systems. By letter dated October 12, 1990, EPRI responded to this concern. Because the staff had not completed its review when the DSER for Chapter 13 was issued, it identified soil-structure interactions as an open issue in the DSER.

Section 2.3.5.2 of Chapter 13 was expanded in Revision 1 to require that plant designers include soil-structure interactions in the foundation design and analysis and identify the basis for the soil (static and dynamic) characteristics allowed in the design analysis. In addition, designers are required to describe the structural design parameters, the controlling physical and geometric parameters, the static and dynamic models used in the systems analysis, and the basis for selecting the design models and the assumed loads. The staff concludes that these revision are acceptable; therefore, this DSER open issue is closed.

3 MAIN TURBINE SYSTEM

Section 3 of Chapter 13 of the Evolutionary Requirements Document provides the definition and performance and equipment requirements for the main turbine system. This system will include the main turbine and the following support subsystems: lube oil system, turbine control system, gland seal system, and instrumentation.

3.1 Main Turbine

The main turbine will include the high- and low-pressure turbines, the turbine stop and control valves, the reheat stop and intercept valves, the turning gears, and other associated piping and equipment.

3.1.1 Safety Classification

Chapter 1 of the Evolutionary Requirements Document references American National Standards Institute/American Nuclear Society (ANSI/ANS) 52.1, "Nuclear Safety Criteria for the Design of Stationary BWRs," as an alternative way of complying with Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive Waste-Containing Components of Nuclear Power Plants." In Section 4.3.A of the DSER for Chapter 1, the staff stated that it had not completely endorsed this industry standard and was concerned about the design and quality assurance requirements of the standard for certain components in the power conversion system and portions of the main turbine system.

In its letter of October 19, 1989, the staff requested that EPRI supply additional information regarding the seismic design of the turbine stop valves and quality assurance criteria for the turbine stop valves, turbine control valves, turbine bypass valves, and main steam leads from the turbine control valves to the turbine casing. By letter dated March 16, 1990, EPRI provided its response. In the DSER for Chapter 13, the staff concluded that EPRI's response was not completely acceptable for BWR designs and identified the following open issues:

- seismic classification of main steamline
- seismic qualification by experience
- seismic design of BWR turbine stop valves
- inspection and quality assurance

The staff's evaluation of the first three issues is given below. The fourth issue is discussed in Section 3.1.2.

<u>Seismic Classification of Main Steamline</u>

The staff discusses this issue in detail in Section 2.3.1 of Appendix B to Chapter 1 of this report. Those portions of the main steamline that are applicable to the main turbine are included.

Seismic Qualification by Experience

In Section 3.1.1 of the DSER for Chapter 13, the staff discussed its concern regarding the definition of seismic Category II in Chapter 1 of the original Evolutionary Requirements Document and identified it as an open issue.

Position C.2 in Regulatory Guide (RG) 1.29, "Seismic Design Classification," addresses non-seismic Category I items whose failure could reduce the functioning of any safety-related item to an unacceptable safety level. These items should be designed and constructed so that the safe shutdown earthquarke (SSE) would not cause such a failure. Section 4.5.4.8 of Chapter 6 of the Evolutionary Requirements Document allows the use of the seismic experience data base as the basis for qualifying these items, and if a seismic analysis is required, the plant designer is allowed to use the simplified analysis procedure described in RG 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Plants." The staff concludes that this position is not completely acceptable. Its position on the use of the seismic experience data base for piping and equipment is discussed in Chapter 1, Section 4.8.1, of this report. In addition, to satisfy RG 1.29 and Item II.h in SRP Section 3.7.3, "Seismic Subsystem Analysis," and Item II.k in SRP Section 3.9.2, "Dynamic Testing and Analysis of Systems, Components, and Equipment," these non-seismic Category I items should be analyzed to SSE loading conditions using the same criteria as those that are applicable to a seismic Category I item. The guidelines in RG 1.143 allow a simplified analysis using only the operating basis earthquake loading conditions and are not acceptable. Therefore, during its reviews of individual applications for FDA/DC, the staff will evaluate, on a case-by-case-basis, the use of the seismic experience data base for structures. If analyses are required, such reviews will be in accordance with RG 1.29 and SRP Sections 3.7.3 and 3.9.2. Therefore, this DSER issue is closed. The overall requirement involving the use of the seismic experience data base for the seismic qualification of certain equipment is discussed further by the staff in Section 4.8.1 of Chapter 1 of this report.

Seismic Design of BWR Turbine Stop Valves

The turbine stop valve is not required to be classified as seismic Category I; however, Position C.1.e of RG 1.29 states that it should be designed to withstand the SSE and maintain its integrity. In a letter dated May 17, 1990, the staff requested that EPRI revise Section 3.3.1.1.2.11 of Chapter 13 to change the requirement that the turbine stop valve be designed to seismic Category II criteria to a requirement that it be designed in accordance with Positions C.1.e and C.2 in RG 1.29. This was identified as an open issue in the DSER for Chapter 13. In Revision 3, EPRI responded to this request by placing requirements in Chapters 2 and 13 of the Evolutionary Requirements Document to satisfy Position C.1.e, including a new Section 4.5.4.8 in Chapter 6 to satisfy Position C.2.

The revised requirements of Chapters 2 and 13 state that the turbine stop valve and piping to the turbine casing will be included in the mathematical model for the dynamic seismic analysis of the main steamlines and branch line piping. The dynamic input loads for these analyses will be derived from a time history model analysis or an equivalent method. These analyses will demonstrate the capability of the turbine stop valve to withstand the SSE design loads, in combination with other appropriate loads, within the limits specified for ASME Code, Section III, Class 2 pipe. The staff concludes that implementation of these requirements will provide reasonable assurance of the integrity of the turbine stop valve and piping to the turbine. Position C.1.e in RG 1.29 is satisfied and these requirements are acceptable. Therefore, this DSER open issue is closed.

3.1.2 Inspection and Quality Assurance

In Section 3.1.2 of the DSER for Chapter 13, the staff identified a concern regarding inspection and quality assurance guidelines for the BWR turbine stop valves, turbine control valves, turbine bypass valves, and main steam leads from the turbine control valve to the turbine casing. For a BWR without the intermediate shutoff valve in the main steamline between the outside isolation valve and the turbine stop valve, the staff's position is that the guidelines in SRP Section 3.2.2, "System Quality Group Classification," Appendix A, should be included in the Evolutionary Requirements Document. This was identified as an open issue in the DSER for Chapter 13. In a letter dated November 6, 1991, EPRI submitted a response to this issue. This response contained a revision to Section 3.1.1.2.10 of Chapter 13 that requires that the turbine stop, control, and bypass valves and the main steam leads from the turbine control valves to the turbine meet the quality group classifications specified in SRP Section 3.2.2, Appendix A, including the footnotes in Table A-1. The staff concludes that this is acceptable; therefore, this DSER open issue is closed.

In addition, although EPRI specifies a design life of 60 years and proposes to extend the interval between turbine inspections and overhauls, the Evolutionary Requirements Document, although it does provide requirements for accessibility in Section 3.3.1.2, does not include requirements for inspection activities, such as boroscopic examinations, nondestructive examination (NDE) of high-stress areas, or component alignments. This is especially important because of the proposed load-following duty cycles and reject capability. In the DSER for Chapter 13, the staff stated that EPRI should address this matter and identified it as an open issue. EPRI has stated that turbine inspections are beyond the scope of the Evolutionary Requirements Document. The staff, therefore, will review individual applications for FDA/DC or a combined license to ensure that applicants provide requirements for turbine inspection, such as NDE methods, and a list of components to be inspected for NRC staff review and approval before plant operation. Therefore, this DSER open issue is closed.

3.1.3 Maintenance

Expanded operating requirements to allow on-line maintenance of the turbine during periods of degradation of support systems have been included in Chapter 13 of the Evolutionary Requirements Document. Although the staff has no objection to proposed operating modes, allowing them can create conditions that impose added stress and harsher operating environments on the machine. First, Section 3.2.1.6 of Chapter 13 indicates that long-term operation at full power can be accommodated with reheat are partially or fully out of service. This can result in the movement of the point of moisture formation in the low-pressure turbine stages. When added to the other requirements that allow cycling and reduced power operation, the staff concludes that this may necessitate the increased use of blade coatings and internal moisture-removal devices and capacity. Furthermore, this operation could also change the conditions and use of extraction steam from these turbines. Second, Section 3.2.1.5 of Chapter 13 specifies that the turbine will be able to operate at up to 70 percent of full load with one string of either high-pressure or low-pressure feedwater heaters out of service (bypassing of heater strings will not be allowed). This reduction in extraction steam flow will have to be accommodated by higher flows in the later stages of the turbine. Finally, Section 3.2.1.4 of Chapter 13 specifies a turbine performance requirement that the system be able to handle a load-following duty cycle. This operation will also place added stress on the turbine and its support systems that must be accommodated in the design. Although the Evolutionary Requirements Document states that the turbine will be able to handle these conditions without deleterious effects, attention needs to be focused on the final designs and testing by the vendor to ensure that the performance and safety requirements are satisfactorily met. The staff will require the ALWR designer or applicant to demonstrate the acceptability of its design.

Although Section 3.3.1.2 of Chapter 13 discusses maintenance of the main turbine, it does not discuss the turbine maintenance program. In its March 22, 1989, request for additional information, the staff asked EPRI to include the turbine maintenance program. The program should require that applicants either (1) submit a turbine maintenance program within 3 years of obtaining an operating license based on the manufacturer's calculations of missile-generation probabilities or (2) volumetrically inspect all low-pressure turbine disks at the second refueling outage and at every other refueling outage thereafter until the staff approves a maintenance program. On August 18 and December 22, 1989, EPRI responded that it considered the maintenance requirement recommended by the NRC to be beyond the scope of the Evolutionary Requirements Document and, therefore, did not include it in Chapter 13.

In the DSER for Chapter 13, the staff identified turbine maintenance as an open issue and concluded that the requirement for the turbine maintenance program was related to the requirement for the missile-generation probability. Because the turbine maintenance program is outside the scope of the Evolutionary Requirements Document, the staff will review individual applications for FDA/DC or a combined license to ensure that applicants provide requirements for a turbine maintenance program for NRC staff review and approval before plant operation. Therefore, this DSER open issue is closed.

3.1.4 Turbine Missiles

General Design Criterion 4 of Appendix A to 10 CFR Part 50 requires that structures, systems, and components important to safety be protected against the dynamic effects that may result from equipment failures, such as the effects of turbine missiles. In support of this requirement, EPRI specifies requirements that will help ensure that the main turbine will be designed and operated in a manner that minimizes the probability that turbine missiles will be generated.

The original version of Chapter 13 of the Evolutionary Requirements Document required that turbine orientation be such that low trajectory missiles resulting from turbine failures do not damage essential plant systems. In a letter dated August 18, 1989, responding to a staff comment, EPRI committed to revise Section 3.3.1.1.1.14 of Chapter 13 to read:

Turbine orientation and placement within the turbine-generator building shall be such that any plane perpendicular to the turbine axis shall not intersect with the primary containment structure. In addition, the probability of unacceptable damage to safety-related systems and components due to turbine missiles shall be shown to be less than 1.0E-7 per year.

In the DSER for Chapter 13, the staff stated that the ALWR low-pressure turbine(s) should meet the specific failure probability of turbine-missile generation related to specific turbine orientation. The failure probability of missile generation for a favorably oriented turbine should be less than 1.0E-4 per reactor-year and for an unfavorably oriented turbine, 1.0E-5 per reactor-year. A turbine is favorably oriented if any plane perpendicular to the turbine-generator axis is not intersected with the primary containment structure. These probabilities originated from the staff's review of Westinghouse and General Electric topical reports on analytical procedures for turbine-missile analyses and were used for recently licensed operating plants. The staff approved the Westinghouse methodology in its SER, "Extension of Turbine Disc Inspection Schedule for Indian Point 3 Nuclear Generating Station," February 2, 1987, and the General Electric methodology in NUREG-1048, "Safety Evaluation Report Related to the Operation of Hope Creek Generating Station," Supplement No. 6, July 1986.

EPRI's proposed probability of unacceptable damage to safety-related systems and components of 1.0E-7 per year satisfies RG 1.115, "Protection Against Low-Trajectory Turbine Missiles," and is acceptable. However, in the DSER for Chapter 13, the staff concluded that the ALWR turbine(s) should also satisfy the failure probability of missile generation of either 1.0E-4 or 1.0E-5 per reactor year, depending on the turbine orientation, and identified this as an open issue.

In Revision 3, EPRI revised Section 3.3.1.1.1.14 of Chapter 13 to require that the failure probability of missile generation for favorable turbine orientation be 1.0E-4 per reactor year and the probability of unacceptable damage to safety-related systems and components resulting from turbine missiles be less than 1.0E-7 per year. EPRI states that the turbine missile generation probability should be based on NRC-approved methodology. The staff concludes that this revision meets the criteria of RG 1.115 and SRP Section 3.5.1.3 "Turbine Missiles," and is acceptable. Therefore, this DSER open issue is closed.

Section 3.2.1 of Chapter 13 also specifies variation in duty cycle that can affect the long-term integrity of the turbine. Examples include operation without reheat, changes from full to partial arc admission, load following, and isolation of feedwater heater strings. These can create fatigue effects, change the location of the point where moisture forms, increase the amount of condensation, or modify stage flows. The staff will consider these issues when it reviews an individual application for FDA/DC.

In addition, applicants should consider the fracture toughness properties of the turbine casing material in specifying the turbine design. This consideration should reflect the potential effects of the environment in which the turbine will operate. This facture toughness consideration is a measure to mitigate the effects of turbine-missile-generating events. The staff will review individual applications for FDA/DC to ensure that appropriate materials have been selected for the turbine casing.

3.1.5 Rotor Disk

Chapter 13 of the Evolutionary Requirements Document proposes changes to the design and operation of the main turbine that will improve the reliability and availability of the unit. Industry has proposed the elimination of the use of shrunk-on rotor disks to solve the fatigue and stress-corrosion-cracking problems of the rotor disk assemblies. EPRI has incorporated this solution into Section 3.3.1.1.1.11 of Chapter 13 by requiring a one-piece rotor using either an integral forging or welded design. Because SRP Section 10.2.3, "Turbine Disk Integrity," gives specific guidelines on fracture toughness, material selection, and inservice inspection primarily for shrunk-on disk designs, and a one-piece disk design will be used in the ALWR, SRP Section 10.2.3 does not apply. Additionally, although not actually specifying materials, EPRI requires that materials, fabrication techniques, and coating processes that have proved to increase resistance to intergranular stress corrosion cracking and to other erosion and corrosion will be used in the designs of rotors, nozzles, and blading. This must be balanced by the requirements proposed by EPRI that the materials selected can be repaired in the field.

In the DSER for Chapter 13, the staff concluded that the use of a one-piece rotor may require that additional emphasis be placed on post-machining inspection and that the Evolutionary Requirements Document should address this matter. This was identified as an open issue.

EPRI stated that the turbine manufacturer routinely includes detailed and documented nondestructive examinations of rotors (and discs, whether separate or not) at various stages in the fabrication process. Provisions for in-process fabrication inspections are not considered to be safety-related issues. Because turbine inspection is beyond the scope of the Evolutionary Requirements Document, the staff will review applications for FDA/DC or a combined license to ensure that applicants provide requirements for stringent post-machining inspections to the NRC staff for review and approval before plant operation. Therefore, this DSER open issue is closed.

3.1.6 Performance Verification

In addition to the dimensional and fitup/assembly checks specified in Section 3.3.1.1.1.19 of Chapter 13, the performance of new or significantly changed designs should be verified through prototype testing. Because Chapter 13 places heavy reliance on the use of turbine-generator components of proven design, the staff does not expect this concern to be an issue. Therefore, it will determine the need for prototype testing of new or significantly changed designs during its reviews of individual applications for FDA/DC.

3.1.7 Turbine Exhaust Boot

In the DSER for Chapter 13, the staff concluded that EPRI had not provided performance requirements for the turbine exhaust boots and identified this lack as an open issue.

In a letter dated March 31, 1992, EPRI stated that the expansion joint between the turbine exhaust hood and the turbine exhaust boot was included in the scope of Chapter 2. Section 4.4.3.13 of Chapter 2 requires that a stainless steel expansion joint and a water seal trough between the condenser and the turbine be provided. A solid connection is permitted if the condenser is spring mounted. The stainless steel expansion joint with a water trough is included specifically to address the air in-leakage reliability requirements for turbine exhaust boots. Additionally, Section 4.5.5.1 of Chapter 1 of the Evolutionary Requirements Document requires that safety-related structures, systems, and components be protected from the dynamic effects of postulated pipe ruptures or designed for the resulting loads. EPRI's requirements satisfy the guidance in SRP 10.2, "Turbine Generator," that the connection joints between the low-pressure turbine exhaust and the main condenser should be arranged to prevent adverse effects on any safety-related equipment in the turbine room in the event of a rupture. Therefore, this DSER open issue is closed.

3.1.8 Nozzle Block Alignment

Problems involving the alignment of nozzle blocks have been suspected of causing several fatigue-related failures of first-stage blading. In the DSER for Chapter 13, the staff concluded that EPRI should address this matter and identified it as an open issue.

In its response dated August 18, 1989, EPRI stated that the alignment of nozzle blocks was highly vendor and turbine model dependent. Additionally, nozzle blocks are realigned each time they are removed for maintenance through clearance checks of the turbine rotor and other stationary components. Therefore, inclusion of a design requirement in Chapter 13 was not desirable to address problems related to misaligned nozzle blocks. Since turbine manufacturers will evaluate problems related to the alignment of nozzle block and the NRC has no regulatory requirements on this issue, this DSER open issue is closed.

3.2 Turbine Lube Oil System

The turbine lube oil system will be designed to provide lubrication to the turbine, generator, and exciter bearings during all normal and abnormal conditions. In addition, the system will act as a backup to the generator hydrogen seal oil system. The NRC has no regulatory requirements concerning the turbine lube oil system. The requirements in Chapter 13 of the Evolutionary Requirements Document for this system reflect standard industry practice and are, therefore, acceptable.

In the DSER for Chapter 13, the staff identified some additional features for EPRI to consider, such as providing sight-glasses and basket strainers in the individual lines to the bearing flow control orifices and provisions for enhancing the collection of oil from leaks. As noted above, there are no regulatory requirements for the turbine lube oil system. Therefore, EPRI was not required to respond to the staff's recommendation.

Additionally, the staff identified the lack of guidance on the design and operation of the radial and thrust bearings as an open issue in the DSER for

Chapter 13. As with the turbine lube oil system noted above, there are no regulatory requirements on the design and operation of radial and thrust bearings. Therefore, this DSER open issue is closed.

3.3 Turbine Control System

Overspeed Limit for Governor

The turbine control system, including the main stop and control valves and the reheat stop and intercept valves, will control the turbine-generator's speed, load, and overspeed. Most of the requirements for this system and its components in Section 3.3.3 of Chapter 13 of the Evolutionary Requirements Document are current and proven, including the requirement that sensing devices and local controllers be radiation resistant for operation in a BWR environment. However, in Section 3.2.3.8 of the original version of Chapter 13, EPRI has relaxed the overspeed point from 103 percent to 105 percent of the rated speed at which the governor would have fully closed the control and intercept valves. In the DSER for Chapter 13, the staff disagreed with EPRI's statement that the basis for this requirement was current practice. The staff needed further justification that the appropriate degree of protection had been maintained and identified this as an open issue.

In response to this open issue, EPRI revised Section 3.2.3.8 of Chapter 13 to require the speed governor for normal speed-load control to fully close the control and intercept valves at 105 percent of normal operating speed. This is consistent with current standard practice. Two independent overspeed trip devices are required (as stated in Sections 3.2.3.14.2 and 3.2.3.1..3 of Chapter 13 of the Evolutionary Requirements Document) that will fully close the turbine valves at 111 percent and 112 percent of normal operating speed. Section 2.3.2.3 of Chapter 13 requires that the natural critical frequencies of the turbine-generator shaft assemblies between zero speed and 20 percent overspeed (120 percent of normal operating speed) be shown by analysis and testing to cause no distress to the unit during operation. On the basis of these additional requirements, the staff concludes that the requirement of 105 percent of the rated speed for normal speed-load control is within the safety analysis limit and is acceptable. Therefore, this DSER open issue is closed.

The turbine overspeed protection system should be designed so that the testing of the turbine overspeed trip features independently verifies the proper functioning of each critical component in the trip system.

Load Shedding Without Turbine Trip

Chapter 13 of the Evolutionary Requirements Document contains operational requirements that the turbine-generator be able to accommodate (1) specific load shedding without turbine trip and (2) 2-hour operation of the turbine-generator with only in-house/hotel loads (offsite power not available). Current systems are not very reliable in handling designed levels of load shedding without a turbine trip. Additionally, the Evolutionary Requirements Document proposes operating conditions that could exist at the time of the load-shedding function that might also complicate turbine control and affect the maintenance of generator voltage and frequency. The designer may have to evaluate the thermal-hydraulics of the steam supply, along with the response capability of the turbine control system, to determine interactions and stability. Turbine control could be in either full or partial arc admission, with the turbine bypass valves in operation, and power-operated relief valves might be cycling. In addition, the chance exists that reheaters or feedwater heaters (extraction steam) will not operate in a normal manner during load shedding. Because all of these could affect the capability to maintain the required tolerances for the electrical power supply to the station loads, additional analyses and/or testing may be necessary to provide assurance that the turbine and control system can respond to variable inlet steam conditions and maintain the electric power output within acceptable tolerances.

In the DSER for Chapter 13, the staff concluded that EPRI should address this matter and identified this as an open issue. In a meeting with the staff on March 31, 1991, EPRI stated that the turbine-generator designer certainly would be expected to address this concern during a specific plant design phase. Since the NRC has no regulatory requirements on this issue, the staff concludes that the issue is closed. However, it will review the detailed system design to determine the adequacy of the turbine control system during its review of an individual application for FDA/DC.

Turning/Straightening Vanes

Turning/straightening vanes are encouraged in Section 3.3.1.1.3.4 of Chapter 13 for the reheat steamlines to reduce possible erosion effects from the vortexes caused by the piping arrangements. In the DSER for Chapter 13, the staff concluded that suitable screens should be required in the reheat stop or intercept valves to ensure loose parts do not enter the low-pressure turbine generators and identified this as an open issue.

In its response dated December 3, 1991, EPRI stated that temporary screens are normally installed in turbine valves following an outage to protect the turbines from foreign objects that may have been inadvertently left in the system during maintenance. These screens are normally removed from the valves after a short period of operation. Requiring the use of screens on a full-time basis may result in a significant reduction in thermal efficiency because of the additional pressure drop across the screens. Since EPRI has provided the information regarding the use of screens inside turbine valves and the NRC has no regulatory requirements on turbine designs, this DSER open issue is closed.

Inservice Inspections

The Evolutionary Requirements Document states that the design of the main stop and control valves and the reheat stop and intercept valves could allow a longer interval between periodic inservice inspections. The staff identified this as an open issue in the DSER for Chapter 13. Although the staff has no reservations regarding design improvements that may allow this extension, it needs more information before it can support lengthening this interval. Therefore, it will review applications for FDA/DC to ensure that any changes to inservice inspection intervals are fully justified by the vendor, and this DSER open issue is closed.

Extraction Steam Check Valves

In the DSER for Chapter 13, the staff stated that although extraction steam check valves were not included with the other turbine valving, EPRI should provided requirements for these valves to ensure that their failure will be minimal and will not affect the safe operation of the turbine during a trip condition and identified this as an open issue.

In its response dated December 3, 1991, EPRI stated that the extraction piping and valves are included within the scope of Chapter 2 of the Evolutionary Requirements Document. Chapter 2 provides specific requirements to address this concern including implementation of the evaluations required by American Society of Mechanical Engineers TDP-2, which address turbine water induction. Sections 3.3.1.4, 3.4.3.6, 3.5.4.7, 4.5.4.2, and 4.5.8.2 of Chapter 2 of the Evolutionary Requirements Document provide the requirements that address this concern. Since the requirements for extraction steam check valves are related to specific plant designs for which the NRC has no regulatory requirements, the staff concludes that this DSER open issue is closed.

Turbine Protection System

The turbine protection system will provide for rapid closure of the main and reheat stop valves and, additionally, the control and intercept valves on receipt of a turbine trip signal. The response of the protection system is necessary to preclude unsafe conditions that could result in turbine damage and the generation of low trajectory missiles. Section 3.3.3.8 of Chapter 13 specifies two independent overspeed trip devices: a mechanical overspeed trip device and an electric device as specified in Table 13.3-1 of Chapter 13 of the Evolutionary Requirements Document, which are also initiated by other diagnostic devices. The staff concludes that the Evolutionary Requirements Document provides for preset levels of turbine protection while increasing reliability and on-line testability.

3.4 Gland Seal System

The turbine gland seal system will provide sealing steam to the annulus space where the turbine rotor shafts and large steam valve shafts penetrate their casings. The sealing portion of the system will prevent air from entering the steam, and the exhaust portion will prevent the release of steam to the atmosphere. Sections 3.2.4 and 3.3.4 of Chapter 13 of the Evolutionary Requirements Document specify the requirements for this system. General Design Criterion 60 and 64 of 10 CFR Part 50, Appendix A, require, in part, that releases of radioactive materials to the environment be controlled and monitored. The gland seal system must, therefore, provide for the collection and condensation of sealing steam and the venting and treatment, if necessary, of noncondensable material. Section 3.2.4.4 of Chapter 13 of the Evolutionary Requirements Document requires that off-gas from the gland steam condenser (BWR) be monitored for radiation and be automatically routed to the gaseous radioactive waste processing system if radioactivity is detected. Additionally, if the exhaust steam is normally radioactive, the off-gas will be routed to the gaseous radioactive waste processing system. The staff concludes that these requirements for controlling and monitoring the release of radioactive material are in accordance with GDC 60 and 64 and are acceptable.

The Evolutionary Requirements Document also establishes as a design margin the capability of the supply and exhaust to accommodate twice the normal gland clearances. However, the turbine designer should evaluate allowable operation with excessive seal clearances to ensure that no abnormal heating occurs in the shaft. The staff will address this matter during its review of an individual application for FDA/DC.

3.5 Instrumentation

Section 3.4 of Chapter 13 of the Evolutionary Requirements Document states that instrumentation will be provided for monitoring thermal, hydraulic, and electrical conditions; controlling equipment components; and initiating alarms and automatic shutdown of the turbine-generator if an unsafe condition occurs. All monitoring instrumentation will be linked to the plant computer.

3.5.1 Turbine Supervisory Instrumentation

The turbine supervisory instrumentation listed in Table 13.3-1 of Chapter 13 will monitor thermal, hydraulic, and mechanical conditions including

- rotor speed
- thrust bearing wear
- journal bearing vibration
- journal and thrust bearing metal temperature
- bearing oil pressure
- bearing oil header temperature
- lube oil reservoir temperature
- rotor eccentricity
- shell expansion
- rotor/shell differential expansion
- turbine water induction detectors
- condenser vacuum
- exhaust hood temperature
- hydraulic control fluid pressure
- stop, governor/control, and intercept valve positions
- stop valve metal temperature (inner and outer)
- first-stage pressure
- reheat stop valve inlet steam temperature
- reheat stop valve inlet steam pressure
- low-pressure inlet metal temperature
- steam seal header temperature
- steam seal header pressure
- gland condenser outlet temperature
- gland condenser pressure

3.5.2 Alarm-Initiating Devices

EPRI requires that devices for the main turbine initiate alarms in the control room for the conditions listed in Table 13.3-1 of Chapter 13. Some of these devices may also initiate turbine trip if the condition is not corrected. These alarms and the responses to these alarms are as follows:

Variable	Response
Rotor speed (high)	Trip
Thrust bearing wear (high)	Trip
Journal bearing vibration (high)	Trip
Journal and thrust bearing metal temperature (high)	Trip
Bearing oil pressure (low)	Trip
Bearing oil header temperature (high)	Alarm only
Lube oil reservoir level (low, low-low, and high)	Alarm only
Lube oil reservoir temperature (high)	Alarm only
Rotor eccentricity (high)	Alarm only
Rotor/shell differential expansion	Trip
Condenser vacuum (low)	Trip
Exhaust hood temperature (high)	Trip
Hydraulic control fluid pressure (low)	Trip
Hydraulic control fluid reservoir level (low and low-low)	Alarm only
First-stage metal temperature (inner and outer)	Alarm only
Steam seal header pressure (low)	Alarm only
Gland condenser pressure (high)	Alarm only

3.5.3 Turbine/Reactor Interface Instrumentation

Section 3.4.3 of Chapter 13 requires a redundant device that will signal to the reactor control system on sensing a turbine trip. This device will be part of the reactor protection system described in Chapter 10 of the Evolutionary Requirements Document. The staff's evaluation of this device is provided in Chapter 10 of this report.

3.5.4 On-Line Diagnostic Instrumentation

Section 3.4.4 of Chapter 13 states that on-line continuous monitoring and trending instrumentation will be required in order to increase plant availability by detecting and locating turbine problems. At a minimum, a system using dual probes and accelerometers on the bearing pedestals will be capable of (1) diagnosing an imbalance in the rotor system, (2) locating a wiped bearing, and (3) locating an oil whirl or whip. EPRI states that this system can help shorten outage time by aiding in the diagnosis and correction of rotor imbalance, which has in the past caused delays at operating LWRs. EPRI recommends that designers consider including additional on-line diagnostic monitoring systems that have a continuous data-collection and trending capability.

3.5.5 Performance Instrumentation

Section 3.4.5 of Chapter 13 states that the turbine will be equipped with sensing points for optional American Society of Mechanical Engineers (ASME) performance tests. The Evolutionary Requirements Document allows the individual utility to select either the full-scale performance tests described in ASME PTC 6, "Steam Turbines Performance Test Code," or the reduced-scope tests described in ASME PTC 6.1, "Alternative Procedure for Testing Steam Turbine."

3.5.6 Solid-State Devices

Section 3.4.6 of Chapter 13 originally stated that all solid-state devices would be capable of withstanding a 2500-V "spike" surge without damage to ensure protection from voltage spikes. EPRI deleted this section from Chapter 13, and voltage surge testing is now addressed in Chapter 10. The staff's evaluation is given in Chapter 10 of this report.

3.5.7 Bearing Oil Drain Flow

Section 3.4.6 of Chapter 13 specifies that some means will be provided for verifying the flow of oil draining from the bearings.

4 MAIN GENERATOR SYSTEM

Section 4 of Chapter 13 of the Evolutionary Requirements Document defines the main generator system and provides performance and equipment requirements for the main generator and the following subsystems:

- excitation
- stator cooling water
- hydrogen cooling
- hydrogen seal oil
- generator hydrogen and carbon dioxide
- generator control

4.1 Main Generator

The main generator will convert rotational energy produced by the main turbine into electrical power. Typical components of the main generator will include

- generator stator frame
- stator core and windings
- generator rotor
- field windings
- collector rings and brushes
- high voltage bushings
- bushing current transformer assembly
- grounding system

The interfaces the main generator system will share with other systems are described in Section 4.1.3.1.2 of Chapter 13 of the Evolutionary Requirements Document.

4.1.1 Performance and Operational Requirements

Section 4.2.1 of Chapter 13 states that the main generator will be designed to produce its rated electrical output when driven at the rated torque produced by the turbine. It will be capable of continuous operation at any loading up to the rated maximum output and of withstanding all expected operating transients resulting from rapid load changes and fault conditions on transmission lines.

Section 4.2.1.2 of Chapter 13 states that the generator will be designed to operate under a number of abnormal conditions. The rotor will be capable of withstanding a 20-percent overspeed without sustaining damage. The generator will be capable of operating at a reduced level of load with reduced hydrogen pressure and without stator cooling. The stator windings will be capable of operating at 130 percent of their rated armature current for 1 minute, and the field (rotor) windings will be capable of operating two times a year at a field voltage of 125 percent of rated load field voltage for 1 minute.

The Evolutionary Requirements Document does not include any requirements for shop or prototype testing of new or significantly changed designs that would ensure the successful operation of the generator and excitor. Since Chapter 13 places heavy reliance on the use of proven turbine-generator component designs, the staff does not expect this concern to be an issue. It will determine the need for such testing during its review of an individual application for FDA/DC.

4.1.2 Systems and Equipment Requirements

Section 2.2.1 of Chapter 13 requires that the main generator be designed to be highly reliable over a 60-year design life. To increase reliability, EPRI specifies the use of improved materials, such as 18Mn-18Cr retaining rings for the rotor, and proven design for the stator and rotor cooling and insulation. The Evolutionary Requirements Document calls for care to be exercised to minimize vibration and ensure adequate lubrication.

4.2 Excitation System

The excitation system will supply and control the direct current for the field winding of the generator. It will also control the voltage and reactive volt-ampere output of the main generator by controlling its excitation. Typically, components of the excitation system will include the following:

- excitation power transformer
- power rectifier assembly
- voltage regulation equipment
- field de-excitation equipment
- exciter protection relaying and monitoring equipment

The interfaces the excitation system will share with other systems are described in Section 4.1.3.2.2 of Chapter 13.

EPRI intends that its proposed requirements for the excitation system render that system capable of operating under a variety of abnormal operating conditions without incurring any degradation. Section 4.2.2.1 of Chapter 13 states that the requirements are the same as those for current generator designs.

EPRI provides for the use of either a static exciter, which will be designed for improved reliability and reduced maintenance, or a conventional rotating exciter.

4.3 Stator Cooling Water System

The stator cooling water system will remove heat from the generator stator and send it to the turbine building component cooling water system. On the basis of the generator vendor's design, EPRI indicates that the stator will be cooled by either water or hydrogen. The stator cooling water system could also cool the exciter and isophase bus systems. The staff concludes that these provisions do not conflict with current regulatory requirements and are acceptable.

4.4 Hydrogen Cooling System

The hydrogen cooling system will send heat produced by ohmic and mechanical losses in the generator to the component cooling water system in the turbine building. It typically will have two water-cooled hydrogen coolers (heat exchangers) capable of full-load operation of the generator if any major active components (i.e., pumps and control valves) are out of service. Section 4.3.4 of Chapter 13 of the Evolutionary Requirements Document specifies the fouling resistance of the coolers and requires that they be constructed of materials suitable for the cooling water chemistry.

4.5 Hydrogen Seal Oil System

The hydrogen seal oil system will prevent generator hydrogen from leaking from the shaft penetrations into the atmosphere; it also will prevent air from leaking into the hydrogen. Section 4.3.5 of Chapter 13 of the Evolutionary Requirements Document proposes that the ac-powered main seal oil pump have a dc-powered and controlled pump for emergencies. Section 3.3.2 of Chapter 13 specifies that the turbine lube oil system will provide a constant source of makeup oil to the seal oil system. Further backup for this system from a connection to the turbine lube oil system can be used after the hydrogen pressure has been reduced to a value lower than the lube oil pressure. In the DSER for Chapter 13, the staff expressed its concern that the continuous makeup of seal oil from the lube oil system could mask seal oil leakage into the generator until hydrogen gas contaminants are diagnosed. It concluded that it was not clear what provisions were being made for monitoring or detecting this leakage and identified this as an open issue.

In its response dated December 3, 1991, EPRI stated that features for monitoring and/or detecting hydrogen seal oil leakage are normal design features for generator seal oil systems and the Evolutionary Requirements Document does not normally include requirements for standard design features. Since the issue is related to a specific plant design for which the NRC has no regulatory requirements, the staff concludes that this DSER open issue is closed.

4.6 Generator Hydrogen and Carbon Dioxide System

Sections 4.2.6 and 4.3.6 of Chapter 13 of the Evolutionary Requirements Document give the requirements for the generator hydrogen and carbon dioxide system. This system will maintain hydrogen pressure and purity in the generator to avoid explosive mixtures and electrical faults that could result from high moisture. The system will also serve to purge the main generator with carbon dioxide. The staff concludes that the proposed performance requirements for this system do not conflict with regulatory requirements and are acceptable.

4.7 Generator Control Systems

Sections 4.2.7 and 4.3.7 of Chapter 13 of the Evolutionary Requirements Document give the requirements for the generator control systems, which will contribute to safe startup, safe operation, and safe shutdown of the generator.

4.8 Instrumentation

Section 4.4 of Chapter 13 of the Evolutionary Requirements Document states that instrumentation will be provided for monitoring thermal, hydraulic, and electrical parameters; controlling equipment components; and initiating alarms and automatic shutdown of the turbine-generator in the event of an unsafe condition. All monitoring instrumentation will be linked to the plant computer.

In its DSER for Chapter 13, the staff stated that EPRI should evaluate the merits of requiring the use of sensing devices and features other than the generator instrumentation listed, including the following:

- an on-line method for measuring organic material and sulfur compounds in hydrogen
- a method for detecting stator resonance shift
- fiberoptic hot spot and fiberopiic end-turn vibration sensors
- a method for monitoring changes in amplitude and phase angle with load

This was identified as an open issue in the DSER for Chapter 13.

In its response dated December 3, 1991, EPRI stated that Section 4.4.1.3 of Chapter 13 recommends the inclusion of additional on-line diagnostic monitoring systems with continuous data-collection and trending capabilities. Since plant designers will evaluate these sensing instrumentation devices using industry codes and/or standards during a specific plant design phase and since the NRC has no regulatory requirements for these devices, this DSER open issue is closed.

5 CONCLUSION

The staff concludes that the EPRI requirements in Chapter 13 of the Evolutionary Requirements Document for the design of the main turbine-generator systems do not conflict with current regulatory guidelines and are acceptable. However, by themselves, they do not provide sufficient information for the NRC staff to determine if the design of the main turbine-generator systems will be adequate. Applicants referencing the Evolutionary Requirements Document will be required to demonstrate compliance with the additional guidance in the Standard Review Plan (NUREG-0800), or provide justification for alternative means of implementing the associated regulatory requirements.

Therefore, the staff concludes that Chapter 13 specifies requirements that, subject to resolution of the identified vendor- and utility-specific items, if properly translated into a design and constructed and operated in accordance with the NRC regulations in force at the time the design is submitted, should result in a nuclear power plant whose main turbine-generator systems will perform as designed and have all the attributes required by the regulations to ensure that there is no undue risk to the health and safety of the public or to the environment.

APPENDIX A
DEFINITIONS AND ACRONYMS

Appendix A of Chapter 13 of the Evolutionary Requirements Document contains definitions of terms and acronyms. The staff has provided a consolidated list of acronyms in Volume 1 of this report.

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The staff of the U.S. Nuclear Regulatory Commission has prepared Volume 2 (Parts 1 and 2) of a safety evaluation report (SER), "NRC Review of Electric Power Research Institute's Advanced Light Water Reactor Utility Requirements Document - Evolutionary Plant Designs," to document the results of its review of the Electric Power Research Institute's "Advanced Light Water Reactor Utility Requirements Document." This SER gives the results of the staff's review of Volume II of the Requirements Document for evolutionary plant designs, which consists of 13 chapters and contains utility design requirements for an evolutionary nuclear power plant (approximately 1300 megawatts-electric).

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