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(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

9.2.2 REACTOR AUXILIARY COOLING WATER SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Plant Systems Branch (PSB)

Secondary - None

I. AREAS OF REVIEW

The PSB reviews reactor auxiliary cooling water systems (CWS) that are required for safe shutdown during normal, operational transient, and accident conditions and for mitigating the consequences of an accident or preventing the occurrence of an accident. These include closed loop auxiliary cooling water systems for reactor system components, reactor shutdown equipment, ventilation equipment, and components of the emergency core cooling system (ECCS).

The review of these systems includes components of the system, valves and piping, and points of connection or interfaces with other systems. Emphasis is placed on the CWS for safety-related components such as LCCS equipment, ventilation equipment, and reactor shutdown equipment. The PSB reviews reactor auxiliary cooling water systems to ensure conformance with the requirements of General Design Criteria 2, 4, 5, 44, 45, and 46.

1. The PSB reviews the capability of the auxiliary cooling systems to provide adequate cooling water to safety-related ECCS components and reactor auxiliary equipment for all planned operating conditions. The review includes the following points:

   a. The functional performance requirements of the system including the ability to withstand adverse operational (i.e., water hammer) and environmental occurrences, operability requirements for normal operation, and requirements for operation during and subsequent to postulated accidents.

USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience

Comments and suggestions for improvement will be considered and should be sent to the U S Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D C 20555

b. Multiple performance functions (if required) assigned to the system and the necessity of each function for emergency core cooling and safe shutdown.

c. The capability of the system surge tank to perform its intended function.

d. The capability of the system to provide adequate cooling water during all operating conditions.

e. The sizing of the system for core cooling and decay heat loads and the associated design margin.

2. Other system aspects that are reviewed include:

a. The effects of non-seismic Category I component failures on the seismic Category I portion of the system.

b. The provisions for detection, collection, and control of system leakage and the means provided to detect leakage of activity from one system to another and preclude its release to the environment.

c. The requirements for operational testing and inservice inspection of the system.

d. The capability of the system to provide adequate cooling to the seals and bearings of all reactor coolant pumps.

e. Instrumentation and control features necessary to accomplish design functions, including isolation of components to deal with leakage or malfunctions and actuation requirements for redundant equipment.

f. A simplified reliability analyses using event-tree and fault-tree logic techniques.

3. PSB also performs the following reviews under the SRP sections indicated:

a. Review of flood protection is performed under SRP Section 3.4.1,

b. Review of the protection against internally-generated missiles is performed under SRP Section 3.5.1.1,

c. Review of the protection of structures, systems and components against the effects of externally-generated missiles is performed under SRP Sections 3.5.1.4 and 3.5.2, and

d. Review of high and moderate energy pipe breaks is performed under SRP Section 3.6.1.

In addition, the PSB will coordinate other branches evaluations that interface with the overall review of the system as follows. The Reactor Systems Branch (RSB) will identify engineered safety feature components associated with the reactor coolant system and the emergency core cooling systems that are required for operation during normal operations, transients, and accident conditions.

RSB will establish cooling load functional requirements and minimum time intervals associated with safety-related components. The RSB performs these reviews as part of its primary review responsibility for SRP Sections 5.4.7, 5.4.8, 6.0, and 15.0. The structural and geotechnical engineering reviewer of the Engineering Branch (EB) will determine the acceptability of the design analyses, procedures, and criteria used to establish the ability of Category I structures that house the system and supporting systems to withstand the effects of natural phenomena such as the safe shutdown earthquake (SSE), the probable maximum flood (PMF), and tornado missiles as part of its primary review responsibility for SRP Sections 3.3.1, 3.3.2, 3.5.3, 3.7.1, 3.7.4, 3.8.4 and 3.8.5. The mechanical engineering reviewer of EB determines that the components, piping and structures are designed in accordance with applicable codes and standards as part of its primary review responsibility for SRP Sections 3.9.1 and 3.9.3. The mechanical engineering reviewer also determines the acceptability of the seismic and quality group classifications for system components as part of its primary review responsibility for SRP Sections 3.2.1 and 3.2.2. The mechanical engineering reviewer also reviews the adequacy of the inservice testing program of pumps and valves as part of its primary review responsibility for SRP Section 3.9.6. The material engineering reviewer of EB verifies that inservice inspection requirements are met for system components as part of its primary review responsibility for SRP Section 6.6 and, upon request, verifies the compatibility of the materials of construction with service conditions. The instrumentation and control systems reviewer and power systems reviewer of the Electrical and Instrumentation Contol Systems Branch (EICSB) will determine the adequacy of the design, installation, inspection, and testing of all essential electrical components, system controls, and instrumentation required for proper operation as part of their primary review responsibilities for SRP Sections 7.1 and 8.1, respectively. The EICSB will review the signals used to isolate safety-related portions of the reactor auxiliary cooling water system from nonsafety-related portions in the event of postulated accidents with special emphasis paid to proper isolation of interconnected trains in the event of unusual conditions such as low pressures in the reactor auxiliary cooling water system or drawing low current for safety-related pumps. The review for Fire Protection, Technical Specifications, and Quality Assurance are coordinated and performed by the Plant Systems Branch, Technical Specification Coordination Branch and the Facility Operations Branch as part of their primary review responsibility for SRP Sections 9.5.1, 16.0, and 17.0, respectively.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

Acceptability of the designs of cooling water systems as described in the applicant's Safety Analysis Report (SAR), including related sections of Chapters 2 and 3 of the SAR, is based on specific general design criteria and regulatory guides, and on independent calculations and staff judgments with respect to system functions and component selection. The design of a CWS is acceptable if the integrated system design is in accordance with the following requirements and recommendations:

1. General Design Criterion 2, as related to structures housing the system and the system itself being capable of withstanding the effects of

earthquakes. Acceptance is based on meeting the guidance of Regulatory Guide 1.29, Position C.1 for safety-related portions and Position C.2 for nonsafety-related portions.

2. General Design Criterion 4, as related to effects of missiles inside and outside of containment, effects of pipe whip, jets and environmental conditions resulting from high and moderate energy line breaks and dynamic effects associated with flow instabilities and attendant loads (i.e., water hammer) during normal plant operation as well as during upset or accident conditions.

3. General Design Criterion 5, as related to shared systems and components important to safety being capable of performing required safety functions.

4. General Design Criterion 44, as its relates to:

   a. The capability to transfer heat leads from safety-related structures, systems, and components to a heat sink under both normal operating and accident conditions.

   b. Component redundancy so that safety functions can be performed assuming a single active component failure coincident with the loss of offsite power.

   c. The capability to isolate components, systems, or piping, if required, so that the system safety function will not be compromised.

   d. Task Action Plan items II.K.2.16 and II.K.3.25 of NUREGs-0718 and 0737 as they related to loss of cooling water to reactor coolant pump (RCP) seals.

   e. A single failure in the CWS does not result in fuel damage or reactor coolant leakage in excess of normal coolant-makeup capability. Single failure includes but is not limited to operator error, spurious activation of a valve operator, and loss of a cooling water pump.

      A moderate-energy leakage crack or an accident that is initiated from a failure in the CWS piping does not result in excessive fuel damage or reactor coolant leakage in excess of normal coolant-makeup capability. A single active failure is considered when evaluating the consequences of this accident. Moderate leakage cracks are determined in accordance with the guidelines of Branch Technical Position ASB 3-1, "Protection Against Postulated Failures in Fluid Systems Outside Containment."

      It has been demonstrated by testing that the reactor coolant pumps will withstand a complete loss of cooling water for 20 minutes, and instrumentation in accordance with IEEE 279 that alarms in the control room is provided to detect a loss of cooling water to ensure a period of 20 minutes is available so that the operator would have sufficient time to initiate manual protection of the plant. Alternatively, if it is not demonstrated by the necessary pump

testing that the reactor coolant pumps will operate for 20 minutes without operator corrective action.

1. Instrumentation in accordance with IEEE 279 is provided consistent with the criteria for the protection system to initiate automatic protection of the plant upon loss of cooling water to a pump. For this case, the component cooling water supply to the seal and bearing of the pump may be designed to nonseismic Category I requirements and Quality Group D, or

2. The component cooling water supply to each pump is designed to be capable of withstanding a single active failure or a moderate-energy line crack as defined in Branch Technical Position ASB 3-1 and to seismic Category I, Quality Group C, and ASME Section III Class 3 requirements.

5. General Design Criterion 45, as related to the design provisions to permit inservice inspection of safety-related components and equipment.

6. General Design Criterion 46, as related to the design provisions to permit operational functional testing of safety-related systems or components to ensure.

   a. Structural integrity and system leak tightness.

   b. Operability and adequate performance of active system components.

   c. Capability of the integrated system to perform required functions during normal, shutdown, and accident situations.

III. REVIEW PROCEDURES

The procedures set forth below are used during the construction permit (CP) application review to determine that the design criteria and bases and the preliminary design as set forth in the preliminary safety analysis report meet the acceptance criteria given in subsection II of this SRP section. For the review of operating license (OL) applications, the review procedures and acceptance criteria given in subsection II will be used to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report.

One of the main objectives in the review of a CWS is to determine its function with regard to safety. Some cooling systems are designed as safety-related systems in their entirety, others have only portions of the system that are safety-related, and others are classified as nonsafety-related because they do not perform any safety function. To determine the safety category of a CWS, the PSB will evaluate its necessity for achieving safe reactor shutdown conditions or for accident prevention or accident mitigation functions. The safety functions to be performed by these systems in all designs are essentially the same, however, the method used varies from plant to plant depending upon the individual designer.

Upon request from the primary reviewer, the coordinating review branches will provide input for the areas of review stated in subsection I of this SRP

section. The primary reviewer obtains and uses such input as required to ensure that this review procedure is complete.

In view of the various designs provided, the procedures set forth below are for a typical CWS designed entirely as a safety-related system. Any variance of the review procedures to take account of a proposed unique design will be such as to ensure that the system meets the criteria of subsection II. The reviewer will select and emphasize material from this SRP section, as may be appropriate for a particular case.

1. The information provided in the SAR pertaining to the design bases and design criteria, and the system description section are reviewed to verify that the equipment used and the minimum system heat transfer and flow requirements for normal plant operations are identified. A review of the system piping and instrumentation diagrams (P&IDs) will show which components of the system are used to:

   a. Remove heat from the reactor primary coolant system necessary to achieve a safe reactor shutdown.

   b. Provide essential cooling for containment components or systems such as the sprays, ventilation coolers, or sump equipment.

   c. Provide cooling for decay heat removal equipment.

   d. Provide cooling for emergency core cooling pump bearings or other emergency core cooling equipment necessary to prevent or mitigate the consequences of an accident.

2. The system performance requirements section is reviewed to determine that it describes allowable component operational degradation (e.g., pump leakage) and describes the procedures that will be followed to detect and correct these conditions when degradation becomes excessive.

3. The reviewer, using the results of failure-modes and -effects analyses, determines that the system is capable of sustaining the loss of any active component and, on the basis of previously approved systems or independent calculations, that the minimum system requirements (cooling load and flow) are met for these failure conditions. The system P&IDs, layout drawings, and component descriptions and characteristics are then reviewed for the following points:

   a. Essential portions of the CWS are correctly identified and are isolable from the nonessential portions of the system. The P&IDs are reviewed to verify that they clearly indicate the physical division between each portion and indicate required classification changes. System drawings are reviewed to see that they show the means for accomplishing isolation and the SAR description is reviewed to identify minimum performance of the isolation valves. The drawings and description are reviewed to verify that automatically operated isolation valves separate nonessential portions and components from the essential portions. Special consideration is given to the case of redundant interconnected trains to assure operation of at least

one safety-related train by proper isolation in the event of an accident or transient.

b. Essential portions of the CWS, including the isolation valves separating seismic Category I portions from the nonseismic portions, are Quality Group C and seismic Category I. System design bases and criteria, and the component classification tables are reviewed to verify that the heat exchangers, pumps, valves, and piping of essential portions of the system will be designed to seismic Category I requirements in accordance with the applicable criteria. The review of seismic design is performed by the structural and geotechnical reviewer of EB and the review for seismic and quality group classification is performed by the mechanical engineering reviewer of EB as indicated in subsection I of this SRP section.

c. The system is designed to provide water makeup as necessary. Cooling water systems that are closed loop systems are reviewed to ensure that the surge tanks have sufficient capacity to accommodate expected leakage from the system for seven days or that a seismic source of makeup can be made available within a time frame consistent with the surge tank capacity (time zero starts at low level alarm). The surge tank and connecting piping are reviewed to ensure that makeup water can be supplied to either header in a split header system. Redundant surge tanks (one to each header) or a divided surge tank design are acceptable to ensure that in the event of a header rupture, the loss of the entire contents of the surge tank will not occur.

d. The system is designed for removal of heat loads during normal operation and of emergency core cooling heat loads during accident conditions, with appropriate design margins to ensure adequate operation. A comparative analysis is made of the system flow rates, heat levels, maximum temperature, and heat removal capabilities with similar designs previously found acceptable. To verify performance characteristics of the system, an independent analysis may be made.

e. Design provisions are made that permit appropriate inservice inspection and functional testing of system components important to safety. The applicant should ensure that the SAR information delineates a testing and inspection program and the system drawings show the necessary test recirculation loops around pumps or isolation valves necessary for this program.

f. Essential portions of the system are protected from the effects of high-energy and moderate-energy line breaks. The system description and layout drawings will be reviewed to ensure that no high- or moderate-energy piping systems are close to essential portions of the CWS, or that protection from the effects of failure will be provided. The means of providing such protection will be given in Section 3.6 of the SAR, and the procedures for reviewing this information are given in the corresponding SRP sections.

g. Essential components and subsystems (i.e., those necessary for safe shutdown) can function as required in the event of a loss of offsite power and instrument air systems. The system design will be acceptable in this regard if the essential portions of the CWS meet minimum

system requirements as stated in the SAR assuming a concurrent failure of a single active component, including a single failure of any auxiliary electric power source. The SAR is reviewed to determine that for each CWS component or subsystem affected by the loss of offsite power or instrument air systems, system flow and heat transfer capability exceed minimum requirements. The results of failure-modes and -effects analyses are considered in ensuring that the system meets these requirements. This will be an acceptable verification of system functional reliability. The effects of loss of cooling water to RCP seals as a result of loss of power will be reviewed as indicated in Task Action Plan items II.K.2.16 and II.K.3.25 of NUREGs-0718 and 0737.

4. The system design information and drawings are analyzed to ensure that the following features will be incorporated.

   a. A leakage detection system is provided to detect component or system leakage. An adequate means for implementing this criterion is to provide sumps or drains with adequate capacity and appropriate alarms in the immediate area of the system.

   b. Components and headers of the system are designed to provide individual isolation capabilities to ensure system function, control system leakage, and allow system maintenance.

   c. Design provisions are made to ensure the capability to detect leakage of radioactivity or chemical contamination from one system to another. Radioactivity monitors and conductivity monitors should be located in the system component discharge lines to detect leakage. An alternative means is to prevent leakage from occurring by operating the system at higher pressure to ensure that leakage is in the preferred direction.

   d. The system is designed to provide cooling to the reactor coolant pump seals and bearings during normal plant operating conditions, anticipated transients, and following postulated accidents. Instrumentation in accordance with IEEE 279 with alarms in the control room should be provided to detect a loss of cooling water in order to ensure that a period of 20 minutes is available to the operator to initiate manual protection of the plant, if necessary. It has been demonstrated by testing that the reactor coolant pumps could potentially operate with loss of cooling water for 20 minutes without the need for operator action.

      As an alternative to pump testing, the reviewer verifies that:

      (1) Instrumentation in accordance with IEEE 279 is provided consistent with the criteria for the protection system to initiate automatic protection of the plant upon loss of water to a pump. For this case, the component cooling water supply to the seal and bearing of the pump may be designed to nonseismic Category I requirements and Quality Group D, or

(2) The component cooling water supply to each pump is designed to be capable of withstanding a single active failure or a moderate-energy line crack as defined in Branch Technical Position ASB 3-1 and to seismic Category D, Quality Group C, and ASME Section III, Class 3 requirements.

5. The reviewer verifies that the system has been designed so that system functions will be maintained as required in the event of adverse environmental phenomena such as earthquakes, tornadoes, hurricanes, and floods. The reviewer evaluates the system using engineering judgment and the results of failure-modes and -effects analyses to determine the following:

   a. The failure of portions of the system or of other systems not designed to seismic Category I standards and located close to essential portions of the system or of non-seismic Category I structures that house, support, or are close to essential portions of the CWS, will not preclude essential functions. The review will identify these nonseismic category components or piping and ensure that appropriate criteria are incorporated to provide isolation capabilities in the event of failure. Reference to SAR Chapter 2, describing site features, and the general arrangement and layout drawings will be necessary as well as the SAR tabulation of seismic design classifications for structures and systems.

   b. The essential portions of the CWS are protected from the effects of floods, hurricanes, tornadoes, and internally- or externally-generated missiles. Flood protection and missile protection criteria are discussed and evaluated in detail under the SRP sections for Chapter 3 of the SAR. The reviewer will use the procedures identified in these SRP sections to ensure that the analyses presented are valid. A statement to the effect that the system is located in a seismic Category I structure that is tornado missile and flood protected or that components of the system will be located in individual cubicles or rooms that will withstand the effects of both flooding and missiles is acceptable. The location and design of the system, structures, and pump rooms (cubicles) are reviewed to determine that the degree of protection provided is adequate.

6. The descriptive information, P&IDs, CWS drawings, and failure-modes and -effects analyses in the SAR are reviewed to ensure that essential portions of the system will function following design basis accidents assuming a concurrent single, active component failure. The reviewer evaluates the information presented in the SAR to determine the ability of required components to function, traces the availability of these components on system drawings, and checks that the SAR information contains verification that minimum system flow and heat transfer requirements are met for each accident situation for the required time spans. For each case, the design will be acceptable if minimum system requirements are met.

7. The SAR is reviewed to assure that the applicant has committed to address the potential for water hammer in the auxiliary cooling water systems and will provide means for prevention, or avoidance, such as

venting and filling capability and operating procedures for avoidance of water hammer.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and his review supports conclusions of the following type to be included in the staff's safety evaluation report:

The reactor auxiliary cooling water systems include pumps, heat exchangers, valves and piping, expansion tanks, makeup piping, and the points of connection or interfaces with other systems. Portions of the reactor auxiliary cooling water systems that are necessary for safe shutdown, accident prevention or accident mitigation are designed to seismic Category I and Quality Group C requirements. Based on the review of the applicant's proposed design criteria, design bases, and safety classification for the reactor auxiliary cooling water systems with regard to the requirements for providing adequate cooling water for the safety-related ECCS components and reactor auxiliary equipment for all conditions of plant operation, the staff concludes that the design of the reactor auxiliary cooling water systems is acceptable and meets the requirements of General Design Criteria 2, 4, 5, 44, 45, and 46. This conclusion is based on the following:

1. The applicant has met the requirements of General Design Criterion 2 with respect to safety-related portions of the systems being capable of withstanding the effects of earthquakes. Acceptance is based on meeting Regulatory Guide 1.29, Position C.1 for the safety-related portions and Position C.2 for the nonsafety-related portions.

2. The applicant has met the requirements of GDC 4 with respect to the effects of missiles inside and outside of containment, effects of pipe whip, jets and environmental conditions resulting from high and moderate energy line breaks and dynamic effects associated with flow instabilities and attendant loads (i.e., water hammer) with respect to impairment of the required functions of auxiliary cooling systems during normal plant operations, and under upset or accident conditions. Acceptance with respect to effects of water hammer is based on the following:

   a. Vents shall be provided for venting components and piping at high points in liquid filled systems which is normally idle and in which voids could occur. These vents should be located for ease of operation and testing on a periodic basis.

   b. Consideration will be given to voiding which can occur following pump shutdown, or during standby. If the system design is such that voiding could occur, means should be provided for a slow system fill upon pump start to avoid water hammer or the system should be designed to maintain function following an inadvertent water hammer occurrence.

   c. Operating and maintenance procedures shall be reviewed by the applicant to assure that adequate measures are taken to avoid water hammer due to voided line conditions.

3. The applicant has met the requirements of General Design Criterion 5 with respect to sharing of structures, systems and components by demonstrating that such sharing does not significantly impair the ability of the reactor auxiliary cooling water systems to perform their safety function, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

4. The applicant has met the requirements of General Design Criterion 44 with respect to cooling water by providing a system to transfer heat from structures, systems and components important to safety to an ultimate heat sink. The applicant has demonstrated that the reactor auxiliary cooling water systems can transfer the combined heat load of these structures, systems and components under normal operating and accident conditions assuming loss of offsite power and a single failure, and that portions of the system can be isolated so that the safety function of the system will not be compromised.

5. The applicant has met the requirements of General Design Criterion 45 with respect to inspection of cooling water systems by providing reactor auxiliary cooling water systems design features which permit inservice inspection of safety-related components and equipment.

6. The applicant has met the requirements of General Design Criterion 46 with respect to testing of cooling water systems by providing reactor auxiliary cooling water systems design features which permit operational functional testing of the system and its components.

7. Also in meeting the requirements of General Design Criterion 44, the applicant has demonstrated that the system can withstand a loss of power without damage to RCP seals in accordance with items II.K.2.16 and II.K.3.25 of NUREGs-0718 and 0737.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's Regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission Regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced Regulatory Guide, NUREGs and implementation of acceptance criterion subsection II.2 is as follows.

(a) Operating plants and OL applicants need not comply with the provisions of this revision.

(b) CP applicants will be required to comply with the provisions of this revision.

VI. REFERENCES

1. General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," of Appendix A to 10 CFR Part 50.

2. General Design Criterion 4, "Environmental and Missile Design Basis."

3. General Design Criterion 5, "Sharing of Structures, Systems, and Components," of Appendix A to 10 CFR Part 50.

4. General Design Criterion 44, "Cooling Water," of Appendix A to 10 CFR Part 50.

5. General Design Criterion 45, "Inspection of Cooling Water System," of Appendix A to 10 CFR Part 50.

6. General Design Criterion 46, "Testing of Cooling Water System," of Appendix A to 10 CFR Part 50.

7. Regulatory Guide 1.29, "Seismic Design Classification."

8. NUREG-0718 "Proposed Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License."

9. NUREG-0737 "Clarification of TMI Action Plan Requirements."