U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

9.5.5 EMERGENCY DIESEL ENGINE COOLING WATER SYSTEM

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of diesel generator support systems

Secondary - None

I. AREAS OF REVIEW

The emergency diesel engine cooling water system (EDECWS) provides cooling water to the station emergency diesel engines and is reviewed for compliance General Design Criteria (GDCs) 2, 4, 5, 17, 44, 45, and 46. The review covers EDECWS portions housed within their respective diesel engine compartments receiving heat from components essential for proper operation of the diesel engines and additional parts of the system transferring the heat to a heat sink. The system includes all valves, heat exchangers, pumps, and piping up to the engine interface.[1]

The specific areas of review are as follow:

1. The EDECWS is reviewed to verify whether:

   A. Each emergency diesel engine has an independent cooling water system.

   B. The system is properly designed, fabricated, erected, and tested to acceptable quality standards.

[1] As defined by the engine manufacturer.

C. The system has boundary divisions between safety-related and nonsafety-related sections.

D. Failure of any nonseismic Category I structure, system, or component (SSC) will not affect EDECWS safety-related functions.

E. Sections of the system important to safety are housed within seismic Category I structures.

F. The consequences of a single active failure in an EDECWS or the loss of a cooling source will not lead to a loss of more than one diesel generator.

G. Instrumentation and control features permit operational testing of the system and assure that normal protective interlocks do not preclude engine operation during emergency conditions.

H. The design includes the capability to detect and control system leakage, including isolation of portions of the system for excessive leakage or component malfunction.

I. Sufficient space permits inspection, cleaning, maintenance, and repair of the system.

J. The design includes measures to preclude long-term corrosion and organic fouling that would degrade system cooling performance and the compatibility of any corrosion inhibitors or antifreeze compounds with system materials.

K. The design addresses EDECWS capacity as to manufacturer recommended engine temperature differentials under adverse operating conditions.

L. EDECWS functional performance characteristics and effects on those characteristics of adverse environmental occurrences, abnormal operational requirements, accident conditions, and loss of offsite power.

2. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this SRP section in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this SRP section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

3. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other SRP sections interface with this section as follows:

1. Upon request, EDECWS review is performed for the compatibility of construction materials with service conditions.

2. Chapter 2: review of functional capability during abnormally high site water levels (probable maximum flood).

3. Sections 3.2.1 and 3.2.2: review of the seismic and quality group classifications for EDECWS components.

4. Sections 3.3.1, 3.3.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4, and 3.8.5: review of the design analyses, procedures, and criteria that establish the ability of structures housing the EDECWS to withstand the effects of natural phenomena like the safe shutdown earthquake, the probable maximum flood, and tornado missiles.

5. Section 3.4.1: EDECWS review for whether protection against flooding is required.

6. Section 3.5.1.1: EDECWS review for whether protection against an internally generated missile is required.

7. Section 3.5.2: EDECWS review for whether protection from tornado missiles is required.

8. Section 3.6.1: review of the plant design for protection against postulated piping failures in fluid systems, including high-energy and moderate-energy piping systems outside containment, and the effect upon the EDECWS.

9. Sections 3.9.1 through 3.9.3: review of EDECWS components, piping, and structures to verify their design per applicable codes and standards.

10. Section 7.1: review of all essential EDECWS instrumentation and controls to determine their design, installation, inspection and testing.

11. Section 8.3.1: review of the adequacy of the design, installation, inspection, and testing of all electrical components (sensing, control, and power) required for proper operation of the system, including interlocks.

12. Section 9.2.1: reviews of the test program for monitoring the heat transfer capability of safety-related heat exchangers cooled by service water. If such tests indicate heat transfer capability degradation that cannot be remedied by maintenance of the service water system, closed loop cooling systems like the EDECWS reviewed under this SRP section should be included in the scope of the inspection and maintenance program for service water systems also reviewed under SRP 9.2.1.

13. Section 9.5.1: EDECWS review for fire protection requirements.

14. Section 14.0: review of the acceptability of the pre-operational and startup tests.

15. Section 16.0: review of EDECWS technical specifications.

16. Chapter 17: review of the quality assurance requirements.

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

II. ACCEPTANCE CRITERIA

Requirements

Acceptability of the emergency diesel engine cooling system design, as described in the applicant's safety analysis report (SAR), COL submission, or design control document is based on specific regulations, GDCs, and regulatory guides (RGs). The reviewer also utilizes information from other federal agencies and published reports, industry standards, military specifications, technical literature on commercially available products, and operational performance data from similarly designed systems at other plants having satisfactory operational experience.

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. GDC 2 as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of natural phenomena like earthquakes, tornadoes, hurricanes, and floods as established in SAR Chapters 2 and 3.

2. GDC 4 as it relates to SSCs that must be protected from, or be capable of withstanding, the effects of externally- and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks.

3. GDC 5 as it relates to the capability of systems and components important to safety shared between units to perform required safety functions.

4. GDC 17 as it relates to EDECWS capability to meet independence and redundancy criteria.

5. GDC 44 for a cooling system with suitable redundancy to transfer heat to an ultimate heat sink under normal operating and accident conditions.

6. GDC 45 for design provisions to permit periodic inspection of safety-related system components and equipment.

7. GDC 46 for design provisions to permit appropriate functional testing of safety-related systems or components for structural integrity, leak-tightness, operability, and performance of active components and system capability function as intended under accident conditions.

8. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria (ITAAC) that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations;

9. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

1. GDC 2 requirements for which SSCs must be protected from, or be capable of withstanding, the effects of natural phenomena like earthquakes, tornadoes, hurricanes, and floods apply to safety-related EDECWS SSCs. The identification of SSC required to withstand earthquakes without the loss of capability to perform safety functions is listed in RG 1.29. Comprehensive compliance with GDC 2 is reviewed under other SRP sections as specified in subsection I of this SRP section.

2. GDC 4 requirements for which SSCs must be protected from, or be capable of withstanding, the effects of externally-and internally-generated missiles, pipe whip, and jet impingement forces of pipe breaks apply to safety-related EDECWS SSCs. Comprehensive compliance with GDC 2 is reviewed under other SRP sections as specified in subsection I of this SRP section.

3. GDC 5 requirements for sharing of SSCs important to safety among nuclear power units are met if each unit has its own diesel generator(s) and each diesel generator has an independent and reliable cooling water system.

4. GDC 17 requirements for the capability of the cooling water system to meet independence and redundancy criteria are met when:

   A. Each diesel generator has a separate and independent EDECWS.

   B. NRC recommendations specified in NUREG/CR-0660, "Enhancement of Onsite Emergency Diesel Generator Reliability," are implemented.

5. GDC 44 requirements are met when the EDECWS has:

   A. The capability to transfer heat from systems and components to a heat sink under transient or accident conditions.

   B. Redundancy of components for performance of safety functions under accident conditions, assuming a single active component failure, or each diesel generator has a separate and independent EDECWS.

   C. The capability to isolate system or piping components if required to maintain the system safety function.

6. GDC 45 as to design provisions for periodic inspection of safety-related system components and equipment.

7. GDC 46 as to design provisions for appropriate functional testing of safety-related systems or components for structural integrity and leak-tightness, operability, performance of active components, and the capability of the system to function as intended under accident conditions.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

1. GDC 2 requires that SSCs important to safety be designed to withstand the effects of natural phenomena like as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform safety functions. The EDECWS safety function is to provide cooling water for the emergency diesel engine (EDE) following an engine start signal. Compliance with GDC 2 requirements ensure that natural phenomena events will not affect EDECWS capability to supply cooling water to the diesel engines.

2. GDC 4 requires that SSCs important to safety be designed to withstand such dynamic effects of pipe ruptures as pipe whip and jet impingement, and externally- or internally-generated missiles. The EDECWS safety function is to provide cooling water to the EDE following an engine start signal. Compliance with GDC 4 provides assurance that the dynamic effects of equipment failures and events external to the plant will not affect EDECWS capability to provide cooling water to the EDEs.

3. GDC 5 prohibits the sharing of SSCs important to safety among nuclear power units unless such sharing can be demonstrated not to impair their ability to perform safety functions, including in an accident in one unit an orderly shutdown and cooldown of the remaining unit. The EDECWS safety function is to provide cooling water to the EDE following an engine start signal. Compliance with GDC 5 provides assurance that EDECWS failure in one unit of the site will not propagate to other units of the site.

4. GDC 17 requires, for the functioning of SSCs important to safety, an onsite electric power system with sufficient independence and redundancy for the performance of safety functions assuming a single failure. Compliance with GDC 17 requirements provide assurance that electric power will be available for systems necessary (i) to prevent fuel damage in anticipated operational occurrences and (ii) to maintain core cooling and containment integrity in postulated accidents.

6. GDC 44 requires a cooling system to transfer heat from SSCs important to safety to an ultimate heat sink. Requirements include suitable redundancy, interconnections, leak detection, and isolation capabilities for onsite power system operation if offsite power is not available. Typically, the emergency diesel generator system is the onsite electric power system relied upon when offsite power is unavailable. The EDECWS is integral to the emergency diesel generator system and transfers heat away from diesel engine components to the ultimate heat sink. GDC 44 provides assurance that important safety functions can be accomplished under normal operating and accident conditions.

7. GDC 45 requires design of cooling water systems for appropriate periodic inspection of important components like heat exchangers and piping to assure system integrity and capability. The EDECWS provides engine cooling for the emergency diesel generator which in turn provides emergency power to plant SSCs important to safety. Periodic EDECWS inspections/tests provide assurance that the system will function as designed to support operation of the onsite emergency power supply.

8. GDC 46 requires design of cooling water systems for appropriate periodic pressure and functional testing under conditions as close to design as practical. The EDECWS provides engine cooling for the emergency diesel generators which in turn provide emergency power to plant SSCs important to safety. Periodic EDECWS inspections/tests provide assurance that the system will function as designed to support operation of the onsite emergency power supply.

III. REVIEW PROCEDURES

The reviewer will select material from the procedures described below, as may be appropriate for a particular case.

These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

EDECWS design may vary considerably from plant to plant due to the requirements of various diesel engine manufacturers, the number and type of secondary cooling loops for heat removal, and the number of intermediate cooling loops required to transfer the rejected heat to the ultimate heat sink. Variations in design also may occur due to performances of various architect-engineer firms. Therefore, for purposes of this SRP section, a typical system is assumed. Any variance in the review procedure to suit a particular design must cover the system review areas in subsection I of this SRP section and the system must meet the criteria in subsection II of this SRP section.

1. The SAR is reviewed to establish that the EDECWS description and related diagrams clearly delineate system operation, individual and total heat removal rates required by components, and the margin in the design heat removal rate capability. The reviewer verifies the following:

   A. The interfacing branches review the seismic design bases and the seismic and quality group classifications as indicated in subsection I of this SRP section. The primary reviewer assures that essential EDECWS portions including the isolation valves separating essential and non-essential portions are classified quality Group C and seismic Category I. SAR component and system descriptions of mechanical and performance characteristics are reviewed for whether the seismic and quality group classifications are included and whether the piping and instrumentation diagrams (P&IDs) indicate any points of change at system or system component interfaces.

   B. Failure of a piping interconnection, as shown on system P&IDs, between subsystems does not cause total EDECWS degradation. Results of failure modes and effects analyses are bases of acceptance.

   C. Provisions are made for inspection of components as shown on system layout drawings.

   D. EDECWS performance and water chemistry complies with engine manufacturer recommendations.

   E. The engine "first try" starting reliability has been increased by an independent loop for circulating heated water while the engine is in the standby mode.

   F. A three-way bypass-type thermostatically-controlled valve controls water flow through the jacket water coolers or radiators to maintain proper coolant temperature at the engine inlet as specified by the manufacturer.

   G. Temperature sensors alert the operator when cooling water temperatures exceed the limits recommended by the manufacturer. The interfacing review branch reviews protective interlocks as indicated in subsection I of this SRP section.

   H. Adequate volume is available to maintain system water level and pump net positive suction head without refill, assuming expected water loss over a seven-day period of engine operation.

2. The reviewer verifies whether the EDECWS can be vented to fill all spaces with water. SAR statements to the effect that the system design satisfies this requirement are acceptable.

3. The reviewer verifies whether system function will be maintained in the event of adverse environmental phenomena and loss of offsite power. The reviewer evaluates the system for whether:

   A. Failure of nonessential EDECWS portions or of other systems not designed to seismic Category I requirements and located close to essential EDECWS portions or failure of nonseismic Category I structures housing, supporting, or located close to essential EDECWS portions will not preclude essential functions. Reference to SAR sections describing site features and the general arrangement and layout drawings as well as the SAR tabulation of seismic design classifications for structures and systems is necessary. SAR statements to the effect that these conditions are met are acceptable.

   B. Essential EDECWS portions are protected from the effects of floods, hurricanes, tornadoes, and internally- and externally-generated missiles. Flood protection and missile protection criteria are evaluated in detail under the SRP sections for Chapter 3 of the SAR. A statement to the effect that the system is located in a tornado-, missile-, and flood-protected seismic Category I structure or that system components are located in individual cubicles or rooms that will withstand the effects of both flooding and missiles is acceptable.

4. The reviewer verifies whether there are high- or moderate-energy piping systems located close to the EDECWS or whether the EDECWS is protected from the effects of postulated breaks in these systems. The means of such protection are in SAR Chapter 3 and procedures for review of such information are in the SRP sections for that chapter.

5. The descriptive information, P&IDs, onsite emergency power supply drawings, and system analyses are reviewed for whether essential portions of the system will function following design basis accidents, assuming a concurrent, single, active component failure. The reviewer evaluates the results of failure modes and effects analyses in the SAR for the functioning of required system portions.

6. The performance requirements of the diesel engine are reviewed to determine the time available to provide cooling water to the diesels and the other systems that must operate to assure onsite power capability.

7. The reviewer verifies whether the EDECWS and the diesel generator can perform for extended periods with less than full electrical power generation without degradation of performance or reliability. A statement to the effect that operating procedures will require loading of the engine up to a minimum of 25 percent of full load or as specified by the manufacturer recommendation for one hour after eight hours of continuous no-load operation or as recommended by the manufacturer is acceptable.

8. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the design control document (DCD). The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

   For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an early site permit (ESP) or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

   For review of both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

9. For reviews under 10 CFR Part 50, the procedures are used during the construction permit review to determine whether the design criteria and bases and the preliminary design as set forth in the preliminary SAR meet the acceptance criteria of subsection II of this SRP section. For the review of operating license (OL) applications, the procedures are used to determine whether the initial design criteria and bases are implemented appropriately in the final design as set forth in the final SAR. OL review procedures include a determination whether the content and intent of the applicant's technical specifications agree with the requirements for system testing, minimum performance, and surveillance developed in the staff review as indicated in subsection I of this SRP section.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

1. The EDECWS includes all piping, valves, heat exchangers, and pumps up to the points where the cooling water piping connects to the engine interfaces. The EDECWS scope of review for the plant included layout drawings, process flow diagrams, piping and instrumentation diagrams, and descriptive information for the system and auxiliary supporting systems essential to its operation. EDECWS essential portions necessary to mitigate the consequences of an accident are designed to seismic Category I and quality Group C.

   The basis for EDECWS acceptance in our review was compliance of the designs, design criteria, and bases with NRC regulations as set forth in the GDCs of Appendix A to 10 CFR Part 50. The staff concludes that the plant design is acceptable and meets the requirements of GDCs 5, 17, 44, 45, and 46. This conclusion is based on the following findings:

A. The applicant has met the requirements of GDC 2, "Design Bases for Protection Against Natural Phenomena," for the ability of structures housing the EDECWS and the EDECWS itself to withstand effects of natural phenomena like earthquakes, tornadoes, hurricanes, and floods, and GDC 4, "Environmental and Dynamic Effects Design Bases." The EDECWS is housed in a seismic Category I structure which protects against the effects of tornados, tornado missiles, turbine missiles, and floods. This protection meets the positions of RGs 1.115, "Protection Against Low-Trajectory Turbine Missiles," Position C.1, and 1.117 "Tornado Design Classification," Appendix Position 13.

B. The applicant has met the requirements of GDC 5, "Sharing of Structures, Systems, and Components," for the capability of shared systems and components important to safety to perform required safety functions. Each unit of the plant has its own emergency diesel generators, each with an EDECWS not shared between other diesel generators.

C. The applicant has met the requirements of GDC 17, "Electric Power Systems," for the capability of the cooling system to meet independence and redundancy criteria and GDC 44 as to the following:

i. The capability to transfer heat from systems and components to a heat sink under transient or accident conditions,

ii. Redundancy of components for performance of safety functions under accident conditions, assuming a single active component failure, and

iii. The capability to isolate components of the system or piping if required for system safety function.

Each EDECWS is independent and physically separated from the other system serving the redundant diesel generator. A single failure in the EDECWS will affect only the associated diesel generator. The EDECWS transfers the heat generated by the diesel to the ultimate heat sink via the heat exchangers and the service water system. The applicant has also met the positions of NUREG/CR-0660, "Enhancement Of Onsite Emergency Diesel Generator Reliability."

D. The applicant has met the requirements of GDC 45 for design provisions for periodic inspections of EDECWS safety-related components and equipment and GDC 46 for design provisions for appropriate functional testing of safety-related systems or components for structural integrity, leak-tightness, operability, and performance of active components and the EDECWS capability to function as intended under accident conditions. To assure structural integrity, leak-tightness, operability, and performance of active components and the capability of the system to function as intended, the EDECWS permits periodic inspection and functional testing during standby and normal modes of power plant operation.

The staff concludes that the EDECWS design complies with all applicable GDCs, RG positions cited, NUREG/CR-0660, staff positions, and industry standards and is therefore acceptable.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this SRP section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection against Natural Phenomena."

2. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Missile Dynamic Effects Design Bases."

3. 10 CFR Part 50, Appendix A, GDC 5, "Sharing of Structures, Systems, and Components."

4. 10 CFR Part 50, Appendix A, GDC 17, "Electric Power Systems."

5. 10 CFR Part 50, Appendix A, GDC 44, "Cooling Water System."

6. 10 CFR Part 50, Appendix A, GDC 45, "Inspection of Cooling Water System."

7. 10 CFR Part 50, Appendix A, GDC 46, "Testing of Cooling Water System."

8. 10 CFR Part 52, "Early site permits; standard design certifications; and combined licenses for nuclear power plants."

9. RG 1.115, "Protection Against Low-Trajectory Turbine Missiles."

10. RG 1.117, "Tornado Design Classification."

11. NUREG/CR-0660, "Enhancement of Onsite Emergency Diesel Generator Reliability." University of Dayton Research Institute; UDR-TR-79-07; February 1979.

12. Diesel Engine Manufacturers Association (DEMA) Standard 1974.