U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 10.4.9 AUXILIARY FEEDWATER SYSTEM (PWR)

REVIEW RESPONSIBILITIES

Primary - Auxiliary and Power Conversion Systems Branch (APCSB)

Secondary - Reactor Systems Branch (RSB)
Electrical, Instrumentation and Control Systems Branch (EICSB)
Structural Engineering Branch (SEB)
Mechanical Engineering Branch (MEB)
Materials Engineering Branch (MTEB)

I. AREAS OF REVIEW

The auxiliary feedwater system (AFS) normally operates during startup, hot standby and shutdown as the feedwater system for pressurized water reactor (PWR) plants. In conjunction with a seismic Category I water source, it also functions as an emergency heat removal system to transfer heat from the primary system when the main feedwater system is not available for emergency conditions including small LOCA cases. The AFS operates over a time period sufficient either to hold the plant at hot standby for several hours or to cool down the primary system, at a rate not to exceed limits specified in technical specifications, to temperature and pressure levels at which the low pressure decay heat removal system can operate.

The APCSB reviews the AFS from the condensate storage tank (normal operation), or the seismic Category I water supply including valving and cross connects (emergency operation), to the connections with the steam generators, which are made either through a connection to the main feedwater piping or through separate auxiliary feedwater piping directly to the steam generators. All inter-connections and cross-connections are included in the review.

The review also includes AFS components, e.g., pumps, valves, and piping, with respect to their functional performance as affected by adverse environmental occurrences, by abnormal operational requirements, and off-normal conditions, e.g., small breaks in the primary system or the loss of offsite power.

The system is reviewed to determine that a single malfunction, a failure of a component, or the loss of a cooling source does not reduce the safety-related functional performance capabilities of the system. The APCSB reviews to assure that:

1. System components and piping have sufficient physical separation or shielding to protect the essential portions of the system from the effects of internally and externally generated missiles.

2. The system satisfies the recommendations of Branch Technical Position APCSB 3-1 with respect to the effects of pipe whip and jet impingement that may result from high or moderate energy piping breaks or cracks (in this regard the AFS is considered to be a high energy system).

3. The system and components satisfy design code requirements, as appropriate for the assigned quality group and seismic classifications.

4. The failure of non-essential equipment or components does not affect essential functions of the system.

5. The system is capable of withstanding a single active failure.

6. The system possesses diversity in motive power sources such that system performance requirements may be met with either of the assigned power sources, e.g., a system with an a-c subsystem and a redundant steam/d-c subsystem.

7. The system design precludes the occurrence of fluid flow instabilities, e.g., water hammer, in system inlet piping during normal plant operation or during upset or accident conditions (see Standard Review Plan 10.4.7).

8. Functional capability is assured by suitable protection during abnormally high water levels (adequate flood protection during the probable maximum flood).

9. The capability exists to detect, collect, and control system leakage and to isolate portions of the system in case of excessive leakage or component malfunctions.

10. Provisions are made for operational testing.

11. Instrumentation and control features are provided to verify the system is operating in a correct mode.

12. The applicant's proposed technical specifications are such as to assure the continued reliability of the AFS during plant operation; i.e., the limiting conditions for operation and the surveillance testing requirements are specified and are consistent with those for other similar plants.

Secondary review evaluations are performed by other branches and the results used by the APCSB to complete the overall evaluation of the system. The secondary reviews are as follows. The RSB identifies any functional interfaces between essential components of the reactor coolant or emergency core cooling systems and the AFS that are required for operation during normal operations or accident conditions. The RSB establishes post-accident heat loads and the associated time intervals available for cooling various components. The RSB also determines the appropriate seismic and quality group classifications. The SEB determines the acceptability of the design analyses, procedures and criteria used for seismic Category I structures that must withstand the effects of natural phenomena such as the safe shutdown earthquake (SSE), the probable maximum flood (PMF), and tornado missiles. The MEB reviews the seismic qualification testing and operability of components and confirms that components, piping, and structures are designed in accordance with applicable codes and standards. The MTEB verifies that inservice inspection requirements are met for system components and, upon request, verifies the compatibility of the materials of construction with service conditions. The EICSB evaluates system controls, instrumentation, and power sources with respect to capability, capacity, and reliability during normal and emergency conditions.

II. ACCEPTANCE CRITERIA

Acceptability of the design of the auxiliary feedwater system, as described in the applicant's safety analysis report (SAR), is based on specific general design criteria and regulatory guides. An additional basis for determining the acceptability of the AFS is the degree of similarity of the design with that for previously reviewed plants with satisfactory operating experience. Listed below are the specific criteria as they relate to the AFS.

1. General Design Criterion 2, as related to structures housing the system and the system itself being capable of withstanding the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods, as established in Chapters 2 and 3 of the SAR.

2. General Design Criterion 4, with respect to structures housing the system and the system itself being capable of withstanding the effects of external missiles and internally generated missiles, pipe whip, and jet impingement forces associated with pipe breaks.

3. General Design Criterion 5, as related to the capability of shared systems and components important to safety to perform required safety functions.

4. General Design Criterion 19, as related to the design capability of system instrumentations and controls for prompt hot shutdown of the reactor and potential capability for subsequent cold shutdown.

5. General Design Criterion 44, to assure:

   a. The capability to transfer heat loads from the reactor system to a heat sink under both normal operating and accident conditions.

b. Redundancy of components so that under accident conditions the safety function can be performed assuming a single active component failure. (This may be coincident with the loss of offsite power for certain events.)

c. The capability to isolate components, subsystems, or piping if required so that the system safety function will be maintained.

6. General Design Criterion 45, as related to design provisions made to permit periodic inservice inspection of system components and equipment.

7. General Design Criterion 46, as related to design provisions made to permit appropriate functional testing of the system and components to assure structural integrity and leak-tightness, operability and performance of active components, and capability of the integrated system to function as intended during normal, shutdown, and accident conditions.

8. Regulatory Guide 1.26, as related to the quality group classification of system components.

9. Regulatory Guide 1.29, as related to the seismic design classification of system components.

10. Branch Technical Positions APCSB 3-1 and MEB 3-1, as related to breaks in high and moderate energy piping systems outside containment.

11. Branch Technical Position APCSB 10-1, as related to auxiliary feedwater pump drive and power supply diversity.

III. <u>REVIEW PROCEDURES</u>

The procedures below are used during the construction permit (CP) 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 Section II of this plan. For operating license (OL) applications, the procedures are utilized 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. The procedures for OL applications also include a determination that the content and intent of the technical specifications prepared by the applicant are in agreement with the requirements for system testing, minimum performance and surveillance developed as a result of the staff's review.

For the purpose of this review plan, a typical system is assumed which has redundant auxiliary feedwater trains, with a 50% capacity motor-driven pump in each train feeding directly to the steam generators, and a 100% capacity steam turbine-driven pump able to supply either of the redundant trains. The pumping capacity is chosen so that the system's is able to hold the plant at hot standby and subsequently to cool down the reactor at specified cooldown rates. This requirement is also met for conditions involving a small break area loss-of-coolant accident (LOCA) or a pipe break outside containment. For cases where there are variations from the typical arrangement, the reviewer adjusts the review procedures to suit the design. However, the system design is required to meet the acceptance criteria given in Section II of this plan.

1. The SAR is reviewed to determine that the system description and piping and instrumentation diagrams (P&IDs) identify the AFS equipment and arrangement that is used for normal operation and for safe plant shutdown (essential) operation. The system P&IDs layout drawings, and component descriptions and characteristics are then reviewed to verify that:

   a. Minimum performance requirements for the system are sufficient for the various functions of the AFS.

   b. Essential portions of the AFS are isolable from non-essential portions, so that system performance is not impaired in the event of a failure of a non-essential component.

   c. Component and system descriptions in the SAR include appropriate seismic and quality group classifications, and the P&IDs indicate any points of change in piping quality group classification.

   d. Design provisions have been made that permit appropriate inservice inspection and functional testing of system components important to safety. It is acceptable if the SAR information delineates a testing and inspection program and if the system drawings show the necessary recirculation loops and around pumps or isolation valves as may be required by this program.

2. The reviewer verifies that the system safety function will be maintained as required, in the event of adverse environmental phenomena, breaks or cracks in fluid system piping outside containment, system component failures, loss of an onsite motive power source, or loss of offsite power. The reviewer uses engineering judgement and the results of failure modes and effects analyses to determine that:

   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 AFS, will not preclude operation of the essential portions of the AFS. Reference to SAR sections 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 protions of the AFS 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 standard review plans for Chapter 3 of the SAR. The location and design of the system, structures, and pump rooms (cubicles) are reviewed to determine that the degree of protection provided is adequate. A statement to the effect that the system is located in a seismic Category I structure that is tornado missile and flood protected, or the components of the system will be located in individual cubicles or rooms that will withstand the effects of both flooding and missiles is acceptable.

c. The essential portions of the system are protected from the effects of high and moderate energy line breaks in accordance with Branch Technical Position APCSB 3-1. Layout drawings are reviewed to assue that no high or moderate energy piping systems are close to essential portions of the AFS, or that protection from the effects of failure will be provided. The means of providing such protection will generally be given in Section 3.6 of the SAR.

d. Essential components and subsystems necessary for safe shutdown can function as required in the event of loss of offsite power. The SAR is reviewed to see that for each AFS component or subsystem affected by the loss of offsite power, system flow and heat transfer capability meet minimum requirements. Statements in the SAR and the results of failure modes and effects analyses are considered in assuring that the system meets these requirements. (CP)

e. The system is designed with adequate redundancy to accommodate a single active component failure without loss of function.

f. Diversity in pump motive power sources and essential instrumentation and control power sources has been provided, in accordance with guidelines of Branch Technical Position APCSB 10-1.

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 auxiliary feedwater system includes all components and equipment from the condensate storage tank (normal operation) or the seismic Category I emergency water supply (including valves and cross-connections) to the connection with the steam generators. The scope of review of the auxiliary feedwater system for the ______________ plant included layout drawings, piping and instrumentation diagrams, and descriptive information for the system and the supporting systems that are essential to its operation. [The review has determined the adequacy of the applicant's proposed design criteria and design bases for the auxiliary feedwater system, and system performance requirements for normal, abnormal, and accident conditions. (CP)] [The review has determined that the design of the auxiliary feedwater system and supporting systems is in conformance with the design criteria and design bases. (OL)]

"The basis for acceptance in the staff review has been conformance of the applicant's designs, design criteria, and design bases for the auxiliary feedwater system and supporting systems to the Commission's regulations as set forth in the general design criteria, and to applicable regulatory guides, staff technical positions, and industry standards.

"The staff concludes that the design of the auxiliary feedwater system conforms to all applicable regulations, guides, staff positions, and industry standards, and is acceptable."

V. REFERENCES

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

2. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Missile Design Bases."

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

4. 10 CFR Part 50, Appendix A, General Design Criterion 19, "Control Room."

5. 10 CFR Part 50, Appendix A, General Design Criterion 44, "Cooling Water."

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

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

8. Regulatory Guide 1.26, "Quality Group Classifications and Standards for water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," Revision 1.

9. Regulatory Guide 1.29, "Seismic Design Classification," Revision 1.

10. Branch Technical Positions APCSB 3-1, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," attached to Standard Review Plan 3.6.1, and MEB 3-1, "Postulated Break and Leakage Locations in Fluid System Piping Outside Containment," attached to Standard Review Plan 3.6.2.

11. Branch Technical Position APCSB 10-1, "Design Guidelines for Auxiliary Feedwater System Pump Drive and Power Supply Diversity for Pressurized Water Reactor Plants."

BRANCH TECHNICAL POSITION APCSB 10-1

DESIGN GUIDELINES FOR
AUXILIARY FEEDWATER SYSTEM PUMP DRIVE AND
POWER SUPPLY DIVERSITY FOR PRESSURIZED WATER
REACTOR PLANTS

A. BACKGROUND

Heat removal from pressurized water reactor plants following reactor trip and a loss of offsite power is accomplished by the operation of several systems including the secondary system via the steam relief system. Similar capability is required to mitigate the consequences of certain postulated piping breaks. Such heat removal involves heat transfer from the reactor to the steam generators, resulting in the production of steam which is then released to the atmosphere. In this process it becomes necessary to supply makeup water to the steam generators. This is accomplished by the use of an auxiliary feedwater system, which generally consists of redundant components that are powered by both electrical and steam-driven sources.

The auxiliary feedwater system functions as an engineered safety system because it is the only source of makeup water to the steam generators for decay heat removal when the main feedwater system becomes inoperable. It must, therefore, be designed to operate when needed, using the principles of redundancy and diversity in order to assure that it can function under postulated accident conditions. The majority of current systems are powered by electrical or steam-driven sources. Operating experience demonstrates that each type of motive power can be subject to a failure of the driving component itself, its source of energy, or the associated control system. The effects of such failures can be minimized by the utilization of diverse systems that include energy sources of at least two different and distinct types.

The provision of several independent flow paths for the auxiliary feedwater system serves to preclude the possibility of a complete loss of function due to a single event, either occurring alone, or in conjunction with the failure of an active component. The auxiliary feedwater system is categorized as a high energy system, because either that section of line which connects to the main feedwater piping or the steam generator is pressurized during plant operation or else the entire system is pressurized when in use during startup, hot standby, and shutdown.

The staff believes that it is necessary to establish design guidelines for the auxiliary feedwater system, and in this regard has developed guidelines that may be used to select the minimum diversity acceptable for auxiliary feedwater system pump drives and power supplies.

B. BRANCH TECHNICAL POSITION

1. The auxiliary feedwater system should consist of at least two full-capacity, independent systems that include diverse power sources.

2. Other powered components of the auxiliary feedwater system should also use the concept of separate and multiple sources of motive energy. An example of the required diversity would be two separate auxiliary feedwater trains, each capable of removing the afterheat load of the reactor system, having one separate train powered from either of two a-c sources and the other train wholly powered by steam and d-c electric power.

3. The piping arrangement, both intake and discharge, for each train should be designed to permit the pumps to supply feedwater to any combination of steam generators. This arrangement should take into account pipe failure, active component failure, power supply failure, or control system failure that could prevent system function. One arrangement that would be acceptable is crossover piping containing valves that can be operated by remote manual control from the control room, using the power diversity principle for the valve operators and actuation systems.

4. The auxiliary feedwater system should be designed with suitable redundancy to offset the consequences of any single active component failure; however, each train need not contain redundant active components.

5. When considering a high energy line break, the system should be so arranged as to permit the capability of supplying necessary emergency feedwater to the steam generators, despite the postulated rupture of any high energy section of the system, assuming a concurrent single active failure.

C. REFERENCES

None

11/24/75

SRP 11.1