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U.S. NUCLEAR REGULATORY COMMISSION
STANDARD REVIEW PLAN
OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 6.2.2 CONTAINMENT HEAT REMOVAL SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Containment Systems Branch (CSB)

Secondary - Auxiliary and Power Conversion Systems Branch (APCSB)
Electrical, Instrumentation and Control Systems Branch (EICSB)
Accident Analysis Branch (AAB)

I. AREAS OF REVIEW

The CSB reviews the information in the applicant's safety analysis report (SAR) concerning containment heat removal under post-accident conditions. The information needed for this review is described in Reference 13. The types of systems provided to remove heat from the containment include fan cooler systems, spray systems, and residual heat removal systems. These systems remove heat from the containment atmosphere and the containment sump water, or the water in the containment wetwell. The CSB review includes the following analyses and aspects of containment heat removal system designs:

1. Analyses of the consequences of single component malfunctions in each system.

2. Analyses of the available net positive suction head (NPSH) to the recirculation heat removal pumps.

3. Analyses of the heat removal capability of the spray water system.

4. Analyses of the heat removal capability of fan cooler heat exchangers.

5. The potential for surface fouling of fan cooler, recirculation, and residual heat removal heat exchangers, and the effect on heat exchanger performance.

6. The quality group classification of each system.

7. The seismic design classification of each system.

8. The design provisions and proposed program for periodic inservice inspection and operability testing of each system or component.

9. The proposed technical specifications for each system.

10. The instrumentation provided to monitor system or component performance.

11. The design of sumps for emergency core cooling and containment spray systems.

12. The effects of debris including insulation on recirculating fluid systems.

The APCSB has the review responsibility for the secondary cooling systems which provide for heat removal from the containment systems to the ultimate heat sink. The APCSB is responsible for determining that the systems supplying cooling water to the heat exchangers in the containment heat removal systems meet the design requirements for engineered safety features.

The EICSB has review responsibility for the sensing and actuation instrumentation for the containment heat removal systems (Standard Review Plan 7.3) and for the qualification test programs for their instrumentation.

The AAB reviews fission product control features of containment spray systems (Standard Review Plan 6.5.2).

II. ACCEPTANCE CRITERIA

General Design Criteria 38, 39, 40, and 50 of 10 CFR Part 50, Appendix A, establish requirements for the design, periodic inspection and operability testing, and functional capability of the containment heat removal systems (Refs. 1, 2, 3, and 4). The items listed below amplify these general requirements and form the basis for the staff's detailed review of containment heat removal systems.

1. The containment heat removal systems should meet the redundancy and power source requirements for an engineered safety feature; i.e., the systems should be designed to accommodate a single active failure. The results of failure modes and effects analyses of each system should assure that the system is capable of withstanding a single failure without loss of function. (See Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," for the definition of Single Failure.)

2. The recirculation spray system is required to circulate water in the containment in the long term (after about one hour) following a loss-of-coolant accident, and should be designed to accomplish this without pump cavitation occurring. Therefore, the net positive suction head available to the recirculation pumps should be greater than the required NPSH. A supporting analysis should be presented in sufficient detail to permit the staff to determine the adequacy of the analysis and should show that the available NPSH is greater than the required NPSH. The analysis will be acceptable if it is done in accordance with the guidelines of Regulatory Guide 1.1, i.e., is based on maximum expected temperatures of the pumped fluid and generally with atmospheric pressure in the containment.

   The recirculation spray system for a subatmospheric containment is designed to start about five minutes after a loss-of-coolant accident; i.e., during the injection phase of spray system operation. For subatmospheric containments, the guidelines of Regulatory Guide 1.1 with regard to containment pressure will apply after the injection phase has terminated, which occurs about one hour after the accident.

3. Analyses of the heat removal capability of the spray system should be based on the following considerations:

   a. The locations of the spray headers relative to the internal structures.

   b. The arrangement of the spray nozzles on the spray headers and the expected spray pattern.

   c. The type of spray nozzles used and the nozzle atomizing capability, i.e., the spray drop size spectrum and mean drop size emitted from each type of nozzle as a function of differential pressure across the nozzle.

   d. The effect of drop residence time and drop size on the heat removal effectiveness of the spray droplets.

   The spray systems should be designed to assure that the spray header and nozzle arrangements produce spray patterns which maximize the containment volume covered and minimize the overlapping of the sprays.

4. The design heat removal capability (i.e., heat removal rate vs. containment temperature) of fan coolers should be established on the basis of qualification tests on production units or acceptable analyses that take into account the expected post-accident environmental conditions and variations in major operating parameters such as the containment atmosphere steam-air ratio, condensation on finned surfaces, and cooling water temperature and flow rate. The equipment housing and ducting associated with the fan cooler system should be analyzed to determine that the design is adequate to withstand the effects of containment pressure following a loss-of-coolant accident (See Standard Review Plan 6.2.5). Fan cooler system designs that contain components which do not have a post-accident safety function, should be designed such that a failure of non-safety related equipment will not prevent the fan cooler system from accomplishing its safety function.

5. The potential for surface fouling of the secondary sides of fan cooler, recirculation, and residual heat removal heat exchangers by the cooling water over the life of the plant and the effect of surface fouling on the heat removal capacity of the heat exchangers should be analyzed and the results discussed in the SAR. The analysis will be acceptable if it is shown that provisions such as closed cooling water systems are provided to prevent surface fouling or surface fouling has been accounted for in establishing the heat removal capability of the heat exchangers.

6. The containment heat removal systems should be designed, fabricated, erected, and tested to Group B quality standards, as recommended by Regulatory Guide 1.26.

7. The containment heat removal systems should be designated Category I (seismic), as recommended by Regulatory Guide 1.29.

8. Provisions should be made in the design of containment heat removal systems for periodic inspection and operability testing of the systems and system components such

as pumps, valves, duct pressure-relieving devices, and spray nozzles. The inspection and test program will be acceptable if it is judged by the CSB to be consistent with that proposed for other engineered safety features.

9. Instrumentation should be provided to monitor containment heat removal system and system component performance under normal and accident conditions. The instrumentation should be capable of determining whether a system is performing its intended function, or a system train or component is malfunctioning and should be isolated. The instrumentation should be redundant and where practical, diverse, and should have readout and alarm capability in the control room.

10. Provisions should be made to allow drainage of spray and emergency core cooling water to the sumps (recirculation piping suction points). The design of protective screen assemblies around recirculation piping suction points will be acceptable if it is capable of preventing debris from entering the recirculation piping which could impair the performance of system pumps, valves, heat exchangers, or spray nozzles. Regulatory Guide 1.82 (Ref. 8) provides guidance on the design of sumps for emergency core cooling and containment spray systems.

III. REVIEW PROCEDURES

The procedures described below provide guidance for the review of containment heat removal systems. The reviewer selects and emphasizes material from the review procedures as may be appropriate for a particular case. Portions of the review may be done on a generic basis for aspects of heat removal systems common to a class of containments, or by adopting the results of previous reviews of plants with essentially the same systems.

CSB assures that the design and functional capability of the containment heat removal system conform to the requirements of General Design Criteria 38, 39, 40, and 50.

CSB determines the acceptability of a containment heat removal system design by reviewing failure modes and effects analyses of the system to be sure that all potential single failures have been identified and no single failure could incapacitate the entire system; comparing the quality standards applied to the system to Regulatory Guide 1.26; comparing the seismic design classification of the system to Regulatory Guide 1.29; reviewing qualification tests performed on system components such as fan coolers; reviewing the system design provisions for periodic inservice inspection and operability testing to ensure that the system and components are accessible for inspection and all active components can be tested; and reviewing the capability to monitor system performance and control active components from the control room so that the operator can exercise control over system functions or isolate a malfunctioning system component.

For plants at the operating license stage of review, the CSB reviews the proposed technical specifications for containment heat removal systems to assure that limiting conditions for operation and surveillance requirements satisfy the intent of General Design Criteria 39 and 40.

CSB reviews analyses of the net positive suction head available to the recirculation pumps since recirculation system operability is contingent upon adequate NPSH being available to preclude pump cavitation. Calculations of the available NPSH are based on transient values of the containment pressure, the vapor pressure of the pumped fluid, the suction head, and the friction head. Containment pressure and vapor pressure head are addressed in Regulatory Guide 1.1, which recommends that the NPSH analyses be based on maximum sump water temperature and, in general, atmospheric containment pressure. CSB reviews the analyses in accordance with the guidelines of Regulatory Guide 1.1. The analyses should provide justification that the assumed accident conditions lead to a conservative prediction of the sump water temperature by discussing the effects of assuming various combinations of operating modes of emergency core cooling equipment and containment heat removal equipment. The conservatism in determining the water level in the containment and the friction losses in the recirculation system suction piping should be justified. For example, the uncertainty in determining the free volume in the lower part of the containment that may be occupied by water, and the quantity of water that may be trapped by the reactor cavity and the refueling canal should be factored into the calculation of the suction head.

The recommendation in Regulatory Guide 1.1 that the calculation of available NPSH be based on the assumption of atmospheric pressure in the containment does not apply directly to subatmospheric containments. The recirculation system in a subatmospheric containment is designed to become operational within five minutes following a loss-of-coolant accident. CSB permits the short-term elevated containment pressure to be used in the calculation of NPSH. After the containment has been depressurized, the subatmospheric pressure that existed in the containment prior to the accident should be used in the calculation.

If in the judgment of the CSB, the NPSH analyses were not done in a sufficiently conservative manner, confirmatory analyses are performed using the CONTEMPT-LT computer code. See References 10, 11, and 12 for a description of this code.

The CSB also reviews the evaluation of the volume of the containment covered by the sprays and the extent of overlapping of the sprays with respect to heat removal capabilities. A judgment will be made regarding the acceptability of the spray coverage and extent of overlapping; the volume of the containment covered by the sprays should be maximized and the extent of overlapping kept to a minimum. Elevation and plan drawings of the containment showing the spray patterns are used to determine coverage and overlapping.

In general, the design requirements for the spray systems with respect to spray drop size spectrum and mean drop size, spray drop residence time in the containment atmosphere, containment coverage by the sprays, and extent of overlapping of the sprays are more stringent when the acceptability of the system is being considered from an iodine removal capability standpoint rather than from a heat removal capability standpoint. Consequently, when the iodine removal capability of the system is satisfied, the heat removal capability will be found acceptable. The Accident Analysis Branch is responsible for determining the acceptability of the iodine removal effectiveness of the sprays (See Standard Review Plan 6.5.2). Since all plants do not use the containment sprays as a fission product removal system, the CSB reviews the system for cases where the system is used only as a heat removal system.

CSB reviews analyses of the heat removal capability of the spray system. This capability is a function of the degree of thermal equilibrium attained by the spray water and the volume of the containment covered by the spray water. The spray drop size and residence time in the containment atmosphere determine the degree of thermal equilibrium attained by the spray water. The CSB confirms the validity of the degree of thermal equilibrium attained using the following information: an elevation drawing of the containment showing the locations of the spray headers relative to the internal structures, including fall heights, and the results of the spray nozzle test program to determine the spectrum of drop sizes and mean drop size emitted from the nozzles as a function of pressure drop across the nozzles.

Reference 9 contains information regarding the heating of spray drops in air-steam atmospheres which can be used to determine the validity of the degree of thermal equilibrium of the spray water used in the analyses.

CSB reviews the adequacy of provisions made to prevent overpressurization of fan cooler ducting following a loss-of-coolant accident (Standard Review Plan 6.2.5). CSB reviews the heat removal capability of the fan coolers. The test programs and calculation models used to determine the performance capability of fan coolers are reviewed for acceptability. If the secondary side of a fan cooler heat exchanger is not a closed system, the CSB reviews the potential for surface fouling. The CSB determines whether or not surface fouling impairs the heat removal capability of a fan cooler.

CSB reviews the system provided to allow drainage of containment spray water and emergency core cooling water to the recirculation suction points (sumps). CSB reviews the design of the protective screen assemblies around the suction points. CSB reviews potential sources of debris including the types of insulation used inside the containment. CSB reviews plan and elevation drawings of the protective screen assemblies, showing the relative positions and orientations of the trash bars or grating and the stages of screening, to determine that the potential for debris clogging the screening is minimized. CSB also reviews the drawings to determine that suction points do not share the same screened enclosure. The effectiveness of the protective screen assembly will be determined by comparing the smallest mesh size of screening provided to the clogging potential of pumps, heat exchangers, valves, and spray nozzles. The methods of attachment of the trash bars or grating and the screening to the protective screen assembly structure should be discussed in the SAR and shown on drawings. A discussion of the adequacy of the surface area of screening with respect to assuring a low velocity of approach of the water to minimize the potential for debris in the water being sucked against the screening should be presented. Regulatory Guide 1.82 (Ref. 8) presents guidelines for the acceptability of the design of containment sumps.

IV. EVALUATION FINDINGS

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

"6.2.2 Containment Heat Removal Systems

The containment heat removal systems include (identify the systems).

"The scope of review of the containment heat removal systems for the __________ plant has included system drawings and descriptive information. The review has included the applicant's proposed design bases for the containment heat removal systems, and the analyses of the functional capability of the systems.

"The basis for the staff's acceptance has been the conformance of system designs and design bases to the Commission's Regulations as set forth in the general design criteria, and to applicable regulatory guides, staff technical positions, and industry codes and standards. (Special problems or exceptions that the staff takes to the design or functional capability of the containment heat removal systems should be discussed.)

"The staff concludes that the design of the containment heat removal systems conforms to all applicable regulations, guides, staff positions, and industry codes and standards, and is acceptable."

V. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 38, "Containment Heat Removal."

2. 10 CFR Part 50, Appendix A, General Design Criterion 39, "Inspection of Containment Heat Removal System."

3. 10 CFR Part 50, Appendix A, General Design Criterion 40, "Testing of Containment Heat Removal System."

4. 10 CFR Part 50, Appendix A, General Design Criterion 50, "Containment Design Basis."

5. Regulatory Guide 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps."

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

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

8. Regulatory Guide 1.82, "Sumps for Emergency Core Cooling and Containment Spray Systems."

9. L. F. Parsly, "Design Considerations of Reactor Containment Spray Systems - Part VI, The Heating of Spray Drops In Air-Steam Atmospheres," ORNL-TM-2412, Oak Ridge National Laboratory, January 1970.

10. R. J. Wagner and L. L. West, "CONTEMPT-LT Users Manual," Interim Report I-214-74-12.1, Aerojet Nuclear Company, August 1973.

11. C. F. Carmichael and S. A. Marks, "CONTEMPT-PS, A Digital Computer Code For Predicting The Pressure-Temperature History Within A Pressure-Suppression Containment Vessel In Response To A Loss-of-Coolant Accident," IDO-17252, Phillips Petroleum Company, April 1969.

12. L. C. Richardson, L. J. Finnegan, R. J. Wagner, and J. M. Waage, "CONTEMPT, A Computer Program For Predicting The Containment Pressure-Temperature Response To A Loss-of-Coolant Accident," IDO-17220, Phillips Petroleum Company, June 1967.

13. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Revision 2.

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