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U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.2.1.1.B ICE CONDENSER CONTAINMENTS

REVIEW RESPONSIBILITIES

Primary - Containment Systems Branch (CSB)

Secondary - None

I. AREAS OF REVIEW

The CSB review of ice condenser containments includes the following areas:

1. The pressure and temperature conditions in the containment due to a spectrum (including break size and location) of loss-of-coolant accidents (i.e., reactor coolant system pipe breaks) and steam and feedwater line breaks.

2. The maximum expected external pressure to which the containment may be subjected.

3. The design of the ice condenser system.

4. The pressure conditions within containment internal structures that act on system components and supports due to high energy line breaks.

5. The maximum allowable operating deck steam bypass area for a full spectrum of reactor coolant system pipe breaks.

6. The design provisions and proposed surveillance program to assure that the ice condenser will remain operable for all plant operating conditions.

7. The design of the return air fan systems.

8. The effectiveness of static and active heat removal mechanisms.

9. The minimum containment pressure that is used in the analyses of emergency core cooling system capability.

10. The range and accuracy of instrumentation that is provided to monitor and record containment conditions during and following an accident.

CSB will coordinate the primary review responsibilities of other branches that interface with the CSB evaluation of the containment functional design. These interfaces include the following:

The Instrumentation and Control Systems Branch (ICSB), as part of its primary responsibility under SRP Section 7.5, evaluates the instrumentation provided to monitor and record containment conditions during and following an accident. The Equipment Qualification Branch (EQB), as part of its primary review responsibility under SRP Section 3.11, will review the acceptability of, and the qualification test program for, the ice condenser components, sensing and actuation instrumentation of the plant protection system and the post-accident monitoring instrumentation and recording equipment. The review of the design adequacy of the containment and its internal structures is coordinated and performed by the Structural Engineering Branch (SEB) as part of its primary review responsibility under SRP Section 3.8. The review of mechanical components and their supports is coordinated and performed by the Mechanical Engineering Branch (MEB), as part of its primary review responsibility under SRP Section 3.9. The Mechanical Engineering Branch (MEB) will review the seismic design and quality group classification of systems and components as part of its primary review responsibility under SRP Section 3.2. The fission product removal capability of the ice condenser is evaluated by the Accident Evaluation Branch (AEB), as part of its primary review responsibility under SRP Section 6.5. The review of proposed technical specifications at the operating license stage of review, pertaining to the surveillance requirements for steam bypass area, return air fan system operability, ice condenser operability, and vacuum relief devices is performed by the Licensing Guidance Branch (LGB) as part of its primary review responsibility under SRP Section 16.0.

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

CSB acceptance criteria are based on meeting the following regulations:

1. General Design Criterion (GDC) 16, as it relates to the reactor containment and associated systems being designed to assure that containment design conditions important to safety are not exceeded for as long as postulated accident conditions require. Since the primary reactor containment is the final barrier of the defense-in-depth concept to protect against the uncontrolled release of radioactivity to the environs, preserving containment integrity under the dynamic conditions imposed by postulated loss-of-coolant accidents is essential.

2. General Design Criterion 50, as it relates to the reactor containment structure and associated heat removal system(s) being designed so that the containment structure and its internal compartments can accommodate the calculated pressure and temperature conditions resulting from any loss-of-coolant accident without exceeding the design leakage rate and with sufficient margin.

3. General Design Criterion 38, as it relates to the containment heat removal system(s) function to rapidly reduce the containment pressure and temperature following any loss-of-coolant accident and maintain them at acceptably low levels.

4. General Design Criterion 39, as it relates to the containment heat removal system(s) being designed to permit periodic inspection of important components to assure their integrity and capability.

5. General Design Criterion 40, as it relates to the appropriate periodic testing to assure system operability.

6. General Design Criterion 13, as it relates to instrumentation and control, requires instrumentation be provided to monitor variables and systems over their anticipated ranges for normal operation and for accident conditions as appropriate to assure adequate safety.

7. General Design Criterion 64, as it relates to monitoring radioactivity releases, requires that means be provided for monitoring the reactor containment atmosphere for radioactivity that may be released from normal operations and from postulated accidents.

Specific criterion or criteria that pertain to design and functional capability of PWR ice condenser containment that are used to meet the relevant requirements of the Commission regulations identified above are as follows:

1. In meeting the requirements of General Design Criteria 16, 38, and 50 regarding the functional capability of the containment and associated heat removal system to preserve containment integrity under postulated high-energy line break accident conditions, the containment pressure and temperature response should be calculated using the LOTIC-1 (or an equivalent) computer code (Ref. 25).

   For plants under review for construction permits, the containment design pressure should provide at least a 20% margin above the highest calculated accident pressure. For plants under review for operating licenses, the highest calculated accident pressure should not exceed the design pressure of the containment.

   The containment pressure and temperature response to postulated secondary system pipe ruptures should be based on the most severe single active failure of the isolation provisions in the secondary system (e.g., main steam isolation valve failure or feedwater line isolation valve failure). The analysis should also be based on a spectrum of pipe break sizes and reactor power levels. The accident conditions selected should result in the highest calculated containment pressure or temperature, depending on the purpose of the analysis. Acceptable methods for the calculation of the containment environmental response to main steam line break accidents are found in NUREG-0588 (Ref. 35).

2. In meeting the requirements of General Design Criterion 50 regarding the integrity of containment internal structures, the containment subcompartment or control volume differential (internal) pressures should be calculated using the Transient Mass Distribution (TMD) computer code (Ref. 22), without the augmented critical flow correlation. TMD should incorporate the heat transfer correlation developed from the 1974

full-scale ice condenser tests and should include the compressibility factor "Y" in the incompressible flow equation.

For plants being reviewed for construction permits, the design differential pressures for all ice condenser control volumes or subcompartments, and system components (e.g., reactor vessel, pressurizer, steam generators) and supports, should provide at least a 40% margin above the highest calculated differential pressures. For plants being reviewed for operating licenses, the highest calculated differential pressures for all ice condenser control volumes or subcompartments should not exceed the corresponding design differential pressures.

The operating deck, steam generator and pressurizer enclosures, and ice condenser lower inlet doors should be designed to withstand the maximum calculated reverse differential pressures between the upper and lower compartments using the LOTIC-2 computer code (Ref. 26). To account for uncertainties in the analysis of reverse differential pressures, an adequate margin should be provided above the maximum calculated reverse differential pressure.

3. In meeting the requirements of General Design Criteria 16 and 38 regarding the functional capability of the containment heat removal system to reduce rapidly, and without exceeding containment design conditions, the containment pressure and temperature under postulated accident conditions, the maximum allowable area for steam bypass of the ice condenser should be greater than the identifiable bypass area for the plant (e.g., the drainage provisions to allow containment spray water to return from the upper compartment to the sumps in the lower compartment). The bypass area capability of the plant should be based on analyses of the spectrum of postulated reactor coolant system pipe breaks, and should be about 35 square feet or greater.

4. In meeting the requirements of General Design Criteria 39 and 40 regarding the inspection and testing of containment heat removal systems, the design of the ice condenser system and return fan system should incorporate provisions for periodic inservice inspection and testing of essential system components; e.g., the ice baskets and doors, the ice condenser temperature monitoring system, the available mass of ice, and return air fan performance and controls.

5. In meeting the requirements of General Design Criterion 16 regarding the containment design conditions important to safety, inadvertent operation of engineered safety features (e.g., the return air fan system or the containment spray system) should not cause the external design pressure of the primary containment to be exceeded. This may be accomplished through conservative containment design, use of vacuum relief devices, or electrical interlocks that preclude inadvertent operation of the spray and fan systems.

6. In meeting the requirements of General Design Criteria 13 and 64, instrumentation capable of operating in the post-accident environment should be provided to monitor the containment atmosphere pressure and temperature and the sump water level and temperature following an accident. The instrumentation should have adequate range, accuracy, and response to assure that the above parameters can be tracked and recorded throughout the course

of an accident. Item II.F.1 of NUREG-0737 and NUREG-0718, and Regulatory Guide 1.97, "Instrumentation For Light-Water-Cooled Nuclear Power Plants to Assess Plant Conditions During and Following an Accident," should be followed.

7. The minimum calculated containment pressure as determined by the LOTIC-2 Code (Ref. 26) should not be less than that used in the analysis of the emergency core cooling system capability (see SRP Section 6.2.1.5, "Minimum Containment Pressure Analysis for Emergency Core Cooling System Performance Capability Studies").

III. REVIEW PROCEDURES

The procedures described below are followed for the review of ice condenser containments. The reviewer selects and emphasizes material from these procedures as may be appropriate for a particular case. Portions of the review may be carried out on a generic basis for aspects of functional design common to a class of ice condenser containments or by adopting the results of previous reviews of plants with essentially the same containment functional design.

Upon request from the primary reviewer, the coordinated 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 assure that this review procedure is complete.

1. The CSB evaluates the design of the ice condenser type containment by comparing it to the design information presented in Appendices M and N to the D. C. Cook FSAR, and discussed in the staff's safety evaluation report on the plant (Ref. 21). The CSB has reviewed the design of the Cook ice condenser as reported in these documents and has found that it satifies the acceptance criteria stated in subsection II of this SRP section. Any differences from the design reported in the Cook documents are evaluated. The CSB determines that all design changes have been justified.

2. The CSB reviews the analysis of the containment pressure and temperature response to postulated loss-of-coolant accidents. The CSB has reviewed the LOTIC-1 code which is used to determine the containment pressure and temperature response, and has determined that the code is acceptable for containment analysis. The CSB assures that the LOTIC-1 code has been used and that the input assumptions to the code are conservative. Code revisions and improvements will also be considered.

   The CSB reviews the analysis of the containment temperature and pressure response to postulated secondary system pipe ruptures. The NRC staff has reviewed the LOTIC-3 code and has determined that it is acceptable for the calculation of ice condenser containment analysis for steam line break accidents. The CSB assures that the LOTIC-3 code has been used and that plant-sensitive input assumptions used in the analysis of the containment response are conservative.

   CSB determines from the results of analyses of postulated loss-of-coolant accidents and secondary system pipe ruptures that the peak calculated containment pressure does not exceed the design pressure of the containment, for plants at the operating license stage of review. For plants at the construction permit stage of review, the CSB will ascertain from the results of analyses reported in the safety analysis report that the design pressure provides a margin of at least 20% above the maximum calculated pressure.

Upon request of the EQB, the CSB will (a) determine the maximum temperature transients calculated for postulated loss-of-coolant accidents and secondary system pipe ruptures have been considered in establishing the environmental qualification requirements for equipment and components required to mitigate the consequences of loss-of-coolant accidents and secondary system pipe ruptures, respectively; and (b) review the analytical methods and assumptions used in the thermal analysis, if thermal analysis is used to establish the qualification of instrumentation and components for use in superheated steam environments.

The CONTEMPT-4 code is being developed to provide improved capability to analyze the long-term response of an ice condenser containment to a loss-of-coolant accident. When the CONTEMPT-4 code is available, the CSB will perform confirmatory analyses using this code.

3. The TMD code is used to evaluate the transient pressure responses (internal) of the ice condenser containment subcompartments. The code is described in the proprietary report WCAP-8077 (Ref. 22). The TMD code utilizes an ice condenser heat transfer coefficient obtained from the 1974 full-scale section tests of the ice condenser. The TMD code also utilizes a compressibility factor "Y" to account for compressible flow effects. As stated in the D. C. Cook Safety Evaluation Report, the CSB has reviewed the assumptions and equations used in the TMD code and with the exception of the critical flow model used to predict subcompartment vent mass flow rates, has concluded that the TMD code conservatively calculates transient pressure response.

   The TMD code calculates the critical flow of a two-component, two-phase fluid (air, steam, and water) assuming a thermal equilibrium condition. However, a correction factor is then applied to the calculated critical flow. The CSB has not accepted the use of this corrected critical flow, referred to as "augmented flow," and has required that the short-term transient responses of subcompartments be determined using the TMD code without applying a correction factor to the critical flow; i.e., without the "augmented flow" correlation.

   Before accepting the containment transient responses calculated by the TMD code, the CSB reviews the modeling of the containment subcompartments, the size and area of assumed vents between nodes, volumes of nodes, the flow loss coefficients for each vent modeled, and the heat transfer coefficients within the ice condenser.

   The CSB will determine from the safety analysis report that the TMD code, without the "augmented flow" correlation, has been utilized to determine the transient pressure response in each subcompartment that contains a high energy line, and in adjoining subcompartments.

The CSB reviews the maximum calculated differential pressures and pressure profiles for each subcompartment. For plants at the construction permit stage of review, the CSB will ascertain that it is the applicant's intent to design all internal structures with a margin of 40% between the maximum calculated differential pressure and the design differential pressure of the structure or component. At the operating license stage of review, the CSB will ascertain that an appropriate margin exists. However, changes in technology and calculational methods may affect the margin. The CSB will then determine that the maximum calculated differential pressures do not exceed the design differential pressures for the internal structures. When maximum calculated differential pressures which exceed the pressures used in the design of the internal structures are identified, the CSB will request the SEB to evaluate the adequacy of the affected internal structures. The loads on components or their supports installed within the compartment due to possible pressure gradients will be evaluated by MEB. The CSB will coordinate the review of dynamic pressure loads for components and equipment supports, and when the design basis loads have been identified the CSB will request the MEB to evaluate the design adequacy of the components and supports.

Modification to the RELAP4 code to include two-phase, two-component mixtures and ice condenser modeling have been made. This will improve the capability of the code for use in short-term response analysis of ice condenser plants. The CSB will use the RELAP4 code to conduct confirmatory analyses. The COMPARE code is also being modified to permit the short term response analysis of ice condenser plants.

4. The CSB reviews the methods, input assumptions, and results of the applicant's steam bypass analysis. The applicant's analysis should show considerable margin between the maximum tolerable bypass leakage area and the identifiable bypass area required to allow spray water drainage back to the containment sump. The CSB determines the adequacy of the margins provided for the full spectrum of reactor coolant pipe ruptures. Factors affecting the determination include the proposed inspections and tests to determine bypass leakage area and whether the design of the plant will permit access to seals between the upper and lower compartments for inspection.

5. The CSB reviews the initial programs for ice loading and subsequent verification of individual ice basket and total ice loads. In addition, it reviews design provisions for monitoring the status of the ice condenser during plant operation to assure that the ice condenser retains its full capability. The CSB also reviews the aspects of the ice condenser design which will allow inspection and functional testing of ice condenser components during various modes of plant operation. Specific areas to be evaluated are the ice condenser temperature instrumentation system, lower inlet door position monitoring system, proposed ice basket inspection programs to determine total ice weight, proposed inspection and testing programs for intermediate and top deck doors, floor drains, lower inlet doors, ice condenser flow passages, divider barrier seals, and access hatches. The CSB determines that the proposed surveillance programs and attendant design provisions fulfill the intent of General Design Criteria 39 and 40.

6. The CSB reviews the environmental conditions used in the qualification testing of the return air fan system components. The CSB determines

whether the test conditions are representative of post-accident conditions to which the equipment may be subjected. The CSB reviews analyses demonstrating that, where required, the return air fan system and its components are designed to withstand the transient differential pressures to which the systems would be subjected following a loss-of-coolant accident.

The CSB reviews the provisions made in the design of the return air fan system and the proposed program for periodic inspection and functional testing of the system and components for compliance with the intent of General Design Criteria 39 and 40. The CSB determines the acceptability of the proposed periodic surveillance program for the return air fan system, taking into account the extent and frequency of testing proposed and the practices established for previous ice condenser plants.

7. The CSB reviews the analysis of the maximum depressurization transient due to inadvertent operation of the containment sprays or return air fans. The CSB reviews the assumed containment initial conditions, methods of calculation, and spray system efficiency to determine whether the containment depressurization analysis is conservative.

8. The CSB reviews the accuracy and range of the instrumentation provided to monitor the post-accident environment. The ICSB, under SRP Section 7.5, and the EQB, under SRP Section 3.11, have review responsibility for the acceptability of, and the qualification test program for, the sensing and actuation instrumentation of the plant protection system and the post-accident monitoring instrumentation and recording equipment.

9. The CSB reviews the minimum containment pressure analysis for the emergency core cooling system performance evaluation in accordance with SRP Section 6.2.1.5, "Minimum Containment Pressure Analysis for Emergency Core Cooling System Performance Capability Studies."

IV. EVALUATION FINDINGS

The conclusions reached on completion of the review of this section are presented in SRP Section 6.2.1.

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 guides and NUREGs.

VI. REFERENCES

The references for this SRP section are listed in SRP Section 6.2.1.