U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

6.2.1.4 MASS AND ENERGY RELEASE ANALYSIS FOR POSTULATED SECONDARY SYSTEM PIPE RUPTURES

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of containment integrity

Secondary - None

I. AREAS OF REVIEW

The mass and energy release analysis for secondary system pipe ruptures is reviewed to ensure the acceptability of the data used to evaluate the containment and subcompartment functional design.

The specific areas of review are as follows:

1. Sources of Energy: All of the energy sources from steam and feedwater line break accidents that are available for release to the containment are reviewed.

2. Mass and Energy Release Rate: The mass and energy release rate calculations are reviewed.

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3. Single-Failure Analyses: The single-failure analyses performed for steam and feedwater line isolation provisions that would limit the flow of steam or feedwater to the assumed pipe rupture are reviewed.

4. 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.

5. 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. Review of the various types and aspects of the containment design are identified in SRP Section 6.2.1.

2. The seismic classification and system quality group classification of steam and feedwater line isolation valves are reviewed under SRP Sections 3.2.1 and 3.2.2 to determine the acceptability of these valves in limiting the mass and energy releases from the steam and feedwater systems.

3. Postulated pipe break locations and sizes are reviewed under SRP Section 3.6.2.

4. The time assumed for operator action to close the manual valves in the auxiliary feedwater system is reviewed under SRP Section 10.4.9.

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

II. ACCEPTANCE CRITERIA

Requirements

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

1. General Design Criteria (GDC) 50, as it relates to providing sufficient conservatism in the mass and energy release analysis for postulated pressurized-water reactor (PWR) secondary system pipe ruptures to ensure the reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident.

2. 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.

3. 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. Sources of Energy. The sources of energy that should be considered in the analyses of steam and feedwater line break accidents include the stored energy in the affected steam generator's metal, including the vessel tubing, feedwater line, and steamline; stored energy in the water contained within the affected steam generator; stored energy in the feedwater transferred to the affected steam generator before closure of the isolation valves in the feedwater line; stored energy in the steam from the unaffected steam generator(s) before the closure of the isolation valves in the steam generator crossover lines; and energy transferred from the primary coolant to the water in the affected steam generator during blowdown.

   The steamline break accident should be analyzed for a spectrum of pipe break sizes and various plant conditions from hot standby to 102 percent of full power. The applicant need only analyze the 102-percent power condition if it can demonstrate that the feedwater flows and fluid inventory are greatest at full power.

2. Mass and Energy Release Rate. In general, calculations of the mass and energy release rates during a steam or feedwater line break accident should be performed in a conservative manner from a containment response standpoint (i.e., the postaccident

containment pressure and temperature are maximized). The following criteria indicate the degree of conservatism that is desired:

A. Mass release rates should be calculated using the Moody model (Ref. 1) for saturated conditions or a model that is demonstrated to be equally conservative.

B. Calculations of heat transfer to the water in the affected steam generator should be based on nucleate boiling heat transfer.

C. Calculations of mass release should consider the water in the affected steam generator and feedwater line, feedwater transferred to the affected steam generator before the closure of the isolation valves in the feedwater lines, steam in the affected steam generator, and steam coming from the unaffected steam generator(s) as the secondary system is being depressurized before the closure of the isolation valves in the steam generator crossover lines.

D. If liquid entrainment is assumed in the steamline breaks, experimental data should support the predictions of the liquid entrainment model. The effect on the entrained liquid of steam separators located upstream from the break should be taken into account. A spectrum of steamline breaks should be analyzed, beginning with the double-ended break and decreasing in area until no entrainment is calculated to occur. This will allow selection of the maximum release case.

If no liquid entrainment is assumed, a spectrum of the steamline breaks should be analyzed beginning with the double-ended break and decreasing in area until it has been demonstrated that the maximum release rate has been considered.

E. Feedwater flow to the affected steam generator should be calculated considering the diversion of flow from the other steam generators, feedwater flashing, and increased feedwater pump flow caused by the reduction in steam generator pressure. An acceptable method for computing feedwater flow is to assume all feedwater travels to the affected steam generator at the pump runout rate before isolation. After isolation, the unisolated feedwater mass should be added to the affected steam generator.

Operator action to terminate auxiliary feedwater flow will be reviewed under SRP Section 10.4.9.

Any general-purpose thermal-hydraulics computer codes that the responsible reviewing organization for the subject application finds acceptable may be used to compute mass and energy releases from steam and feedwater line break accidents.

3. Single-Failure Analyses. Steam and feedwater line break analyses should assume a single active failure in the steam or feedwater line isolation provisions or feedwater pumps to maximize the containment peak pressure and temperature. For the assumed failure of a safety-grade steam or feedwater line isolation valve, operation of nonsafety-grade equipment may be relied upon as a backup to the safety-grade equipment. In this event, the reviewer will confer with the responsible organizations for SRP Sections 3.2.1, 3.2.2, 3.6.2, and 10.4.9 to ensure a consistent staff position regarding the acceptability of the design criteria for the nonsafety-grade equipment.

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 50 requires the containment structure and associated heat removal systems be designed to accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss of coolant. SRP Section 6.2.1.4 applies the requirements of this GDC to postulated PWR secondary system pipe ruptures to assure that mass and energy inputs are appropriately conservative. A secondary system pipe rupture releases a significant amount of energy which potentially could damage the containment structure or associated systems. Containment, therefore, must be designed to definitively withstand this accident. Meeting the requirements of GDC 50 will ensure that containment integrity is maintained under the most severe secondary system pipe rupture, thus precluding the release of radioactivity to the environment.

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.

1. Sources of Energy. The reviewer evaluates the sources of energy identified by the applicant in the analyses of steam and feedwater line break accidents to ensure that the sources listed in Subsection II of this SRP section have been considered.

   The reviewer also examines the assumptions of the secondary coolant system pipe break analysis to determine whether the applicant has identified the "worstcase" pipe break accident and completed the analysis in a conservative manner from the standpoint of containment pressure and temperature. This review involves the proposed methods and models used for blowdown analyses. The reviewer will evaluate the acceptability of the approach used by the applicant based on the acceptance criteria in Subsection II of this SRP section.

2. Mass and Energy Release Rate. The reviewer evaluates the applicant's calculations for main feedwater flow into the affected steam generator to determine whether the flow rate is conservatively maximized.

   If the applicant's steamline break model calculates liquid entrainment, the reviewer determines the validity of the experimental data provided to support the entrainment calculation. The reviewer will also ascertain whether the analysis considered the effect of steam separators located upstream from the postulated steamline break. The reviewer evaluates comparisons to experimental data made by the applicant and makes comparisons to other available experimental data to determine the amount of conservatism in the mass and energy release models.

The reviewer examines the results of a spectrum of steamline breaks, beginning with the double-ended break and decreasing in area until no entrainment occurs, to ensure that the applicant has identified the steamline break size producing the highest containment temperature and pressure.

The reviewer may perform confirmatory analyses of the containment pressure and temperature response to steam and feedwater line breaks inside the containment using thermal-hydraulic computer codes that the responsible reviewing organization for the subject application finds acceptable.

3. Single-Failure Analyses. The reviewer reviews analyses of postulated single failures of active components in the secondary systems, such as steam and feedwater line isolation valves and feedwater pumps, and determines whether the single failure that maximizes containment pressure and temperature has been selected.

   The reviewer requests the review of SRP Sections 3.2.1, 3.2.2, and 3.6.2 by the responsible organization as to the acceptability of nonsafety valves in limiting the mass and energy releases from the steam and feedwater systems. The reviewer also requests the organization responsible for SRP Section 10.4.9 to review the rationale for determining the time at which operator action can be relied upon to terminate auxiliary feedwater flow to the affected steam generator.

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.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations, if applicable (section III.2) 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.

The evaluation findings will follow the format provided in SRP Section 6.2.1 and conclude that the applicant followed the SRP acceptance criteria identified above [or identified deviations from the SRP acceptance criteria with appropriate justification] and meets GDC 50 as it relates to providing sufficient conservatism in the mass and energy release analysis for postulated pressurized-water reactor (PWR) secondary system pipe ruptures for the containment design basis.

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. F. J. Moody, "Maximum Flow Rate of a Single Component, Two-Phase Mixture," Revision Jour. of Heat Transfer, Trans. Am. Soc. of Mechanical Engineers, Vol. 87, No. 1, February 1965.