U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

6.2.1.2 SUBCOMPARTMENT ANALYSIS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of containment integrity

Secondary - None

The responsible organization reviews the information presented by the applicant in the safety analysis report (SAR) concerning the determination of the design differential pressure values for containment subcompartments. A subcompartment is defined as any fully or partially enclosed volume within the primary containment that houses high-energy piping and would limit the flow of fluid to the main containment volume in the event of a pipe rupture within the volume. This is referred to as an internal compartment in general design criterion (GDC) 50, of Appendix A to 10 CFR Part 50. A short-term pressure pulse would exist inside a containment subcompartment following a pipe rupture within the volume. This pressure transient would produce a pressure differential across the walls of the subcompartment which would generally reach a maximum value within the first second after blowdown begins. The magnitude of this maximum value is a function of several parameters, which include blowdown mass and energy release rates, subcompartment volume, vent area, and vent flow behavior. A transient differential pressure response analysis should be provided for each subcompartment or group of subcompartments that meets the above definition.

I. AREAS OF REVIEW

The specific areas of review are as follows:

1. Nodalization Schemes: The basis for the nodalization within each subcompartment is reviewed.

2. Initial Thermodynamic Conditions: The initial thermodynamic conditions within each subcompartment are reviewed to ensure the selection of values that maximize the resultant differential pressure.

3. Vent Flow Path and Distribution of Mass and Energy Released: The nature of each vent flow path considered, the distribution of the mass and energy released, and the extent of entrainment assumed in the vent flow mixture is reviewed. The review may also include an analysis of the dynamic characteristics of components, such as doors, blowout panels, or sand plugs, that must open or be removed to provide a vent flow path, as well as the methods and results of component tests performed to demonstrate the validity of these analyses. The analytical procedure used to determine the loss coefficients and inertia terms (L/A, m^{-1} (ft^{-1})) for each vent flow path used to predict the vent mass flow rates is also reviewed.

4. Design Pressure: The design pressure chosen for each subcompartment is reviewed.

5. 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.

6. 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. Review of the break locations and dynamic effects of postulated pipe ruptures and the mechanical design of movable and stationary devices provided for vent flow control in containment subcompartments is performed under SRP Section 3.6.2.

3. Review of those applications that propose to exclude dynamic effects of pipe ruptures, including localized pressurization effects and loads on component supports, is performed under SRP Section 3.6.3.

4. Review of the structural design of movable and stationary devices provided for vent flow control in containment subcompartments is performed under SRP Section 3.8.3.

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 Criterion (GDC) 4, as it relates to the design of containment internal compartments to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. The containment internal compartments shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

2. GDC 50, as it relates to the design of the containment internal compartments to ensure that the reactor containment structure, including access openings, penetrations, and the containment heat removal system are 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.

3. 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.

4. 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. Nodalization Schemes. Subcompartment nodalization schemes should be chosen so that there is no substantial pressure gradient within a node. A sensitivity study which includes increasing the number of nodes until the peak calculated pressures converge to small resultant changes should be used to verify the nodalization scheme. The guidelines of Section 3.2 of NUREG-0609 (Ref. 1) should be followed and a nodalization sensitivity study should be performed, which should include the consideration of spatial pressure variations (e.g., pressure variations circumferentially, axially, and radially within the subcompartment). These variations are use to calculate the transient forces and moments acting on components.

2. Initial Thermodynamic Conditions. The initial atmospheric conditions within a subcompartment should maximize the resultant differential pressure. An acceptable model would assume air at the maximum allowable temperature, minimum absolute pressure, and zero percent relative humidity. If the assumed initial atmospheric conditions differ from this model, the selected values should be justified by the applicant.

   Another acceptable model that may be used for a restricted class of subcompartments involves simplifying the air model outlined above. In this case, the initial atmosphere within the subcompartment is modeled as a homogeneous water-steam mixture with an average density equivalent to the dry air model. This approach should be limited to subcompartments that have choked flow within the vents because the adequacy of this simplified model for subcompartments having primarily subsonic flow through the vents has not been established.

3. Vent Flow Path and Distribution of Mass and Energy Released. Assumptions with regard to the distribution of mass and energy release should be biased towards maximizing the subcompartment pressure. The vent flow behavior through all flowpaths within the nodalized compartment model should be based on a homogeneous mixture in thermal equilibrium, with the assumption of 100-percent water entrainment. In addition, the selected vent critical flow correlation should be conservative with respect to available experimental data. Currently acceptable vent critical flow correlations are the "frictionless Moody" (Ref. 2), with a multiplier of 0.6 for water-steam mixtures, and the thermal homogeneous equilibrium model for air-steam-water mixtures.

   If vent flowpaths are used that are not immediately available at the time of pipe rupture, the following criteria apply:

A. The vent area and resistance as a function of time after the break should be based on a dynamic analysis of the subcompartment pressure response to pipe ruptures.

B. The validity of the analysis should be supported by experimental data, or a testing program should be proposed at the construction permit or DC stage that will support this analysis.

C. To meet the requirements of GDC 4, the safety analysis should consider the effects of missiles that may be generated during the transient.

4. Design Pressure. For the review of a construction permit (CP) preliminary safety analysis report (PSAR) or a factor of 1.4 should be applied to the peak differential pressure which is calculated in a manner acceptable to the reviewer for the subcompartment structure, and the enclosed components for use in the design of the structure and the component supports. For the review of the operating license (OL) final safety analysis report (FSAR), DC or COL FSAR, the peak calculated differential pressure should not exceed the design pressure. It is expected that the peak calculated differential pressure will not be substantially different from that of the construction permit. However, improvements in the analytical models or changes in the as-built subcompartment may affect the available margin.

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 4 allows the dynamic effects associated with postulated pipe ruptures in nuclear power units to be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.

   Demonstration of extremely low probability pipe rupture requires fracture mechanics analysis to evaluate the stability of postulated through-wall flaws in piping and the ability to detect leakage through a flaw before the flaw grows to an unstable size. The concept underlying such analysis is referred to as "leak-before-break" (LBB). Although LBB technology allows applicants to eliminate consideration of local dynamic effects of postulated pipe ruptures in the design basis of an SSC, the staff will continue to require consideration of the global effects of postulated pipe ruptures for the design of subcompartment enclosures because the global effects provide a convenient and conservative design envelope. Containment subcompartments contain high-energy piping that, if ruptured, could cause collapse of the subcompartment, generation of missiles, and creation of harsh local environmental conditions. Meeting the requirements of GDC 4 will help to maintain the structural integrity of containment subcompartments and protect the containment structure and systems from the effects of a high-energy line break.

2. GDC 50 requires that the containment structure and associated heat removal system be designed to accommodate, without exceeding the design leakage rate and with

sufficient margin, the calculated pressure and temperature conditions resulting from a loss of coolant accident. Because a loss-of-coolant accident is the most severe challenge expected, the design of the containment and its subcompartments must be able to withstand such an accident. Providing sufficient design margin will assure that the design can withstand all postulated accidents regardless of unanticipated factors. Meeting the requirements of GDC 50 will help to maintain the structural integrity of containment subcompartments and protect the containment structure and systems from the effects of a subcompartment high-energy line break.

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. Nodalization Schemes. The reviewer evaluates the nodalization of each subcompartment to determine the adequacy of the calculational model. As necessary, the reviewer performs iterative nodalization studies for subcompartments to confirm that the model includes sufficient nodes.

2. Initial Thermodynamic Conditions. The reviewer compares the initial subcompartment air pressure, temperature, and humidity conditions to the criteria in Subsection II of this SRP section to confirm that conservative conditions were selected.

3. Vent Flowpath and Distribution of Mass and Energy Released. The reviewer determines the adequacy of the information in the safety analysis report regarding subcompartment volumes, vent areas, vent resistances, and inertia terms. If a subcompartment must rely on doors, blowout panels, or equivalent devices to increase vent areas, or unique flow-limiting devices to control vent flows, the reviewer evaluates the analysis and testing programs that substantiate their use. The review of the mechanical and structural design of such flow control devices will be performed under SRP Sections 3.6.2 and 3.8.3.

   The reviewer evaluates the bases, correlations, and computer codes used to predict subsonic and sonic vent flow behavior and the capability of the code to model compressible and incompressible flow. The bases should include comparisons of the correlations to both experimental data and recognized alternate correlations that have been accepted by the staff.

   The reviewer may perform a confirmatory analysis of the blowdown mass and energy profiles within a subcompartment. The analysis is done using thermal-hydraulics computer codes that are acceptable to the responsible reviewing organization for the subject application. The purpose of the analysis is to confirm the predictions of the mass and energy release rates appearing in the safety analysis report and to verify that the analysis considered an appropriate break location and size including LBB considerations.

4. <u>Design Pressure</u>. For a CP PSAR, OL, DC, or COL FSAR, the reviewer ascertains that the subcompartment design procedures include appropriate margins above the calculated values, as given in Subsection II. Using the nodalization of each subcompartment as specified in the safety analysis report, the reviewer performs analyses using one of several available computer programs to determine the adequacy of the calculated peak differential pressure. The computer program used will depend upon the subcompartment under review and the flow regime.

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) 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 meet GDC 4 and 50 as they relate to the design of the containment subcompartments.

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. NUREG-0609, "Asymmetric Blowdown Loads on PWR Primary Systems," January 1981.

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