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(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.2.1.2 SUBCOMPARTMENT ANALYSIS

REVIEW RESPONSIBILITIES

Primary - Containment Systems and Severe Accident Branch (SCSB)[1]

Secondary - None

I. AREAS OF REVIEW

The SCSB[2] reviews the information presented by the applicant in the safety analysis report 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 postulated pipe rupture within the volume. A short-term pressure pulse would exist inside a containment subcompartment following a pipe rupture within the volume. This pressure transient produces a pressure differential across the walls of the subcompartment which reaches a maximum value generally within the first second after blowdown begins. The magnitude of the peak 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.

The SCSB[3] review includes the distribution of the mass and energy released into the break compartment, nodalization of subcompartments, subcompartment vent flow behavior, and subcompartment design pressure margins.

The SCSB[4] review of the subcompartment model includes the basis for the nodalization within each subcompartment, the initial thermodynamic conditions within each subcompartment, the

nature of each vent flow path considered, and the extent of entrainment assumed in the vent flow mixture. 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, and the methods and results of components tests performed to demonstrate the validity of these analyses. The analytical procedure to determine the loss coefficients and inertia terms (L/A, m^{-1} (ft^{-1}))[5] for each vent flow path, and to predict the vent mass flow rates, is reviewed. The design pressure chosen for each subcompartment is also reviewed.

Review Interfaces[6]

The SCSB[7] will coordinate other branches'[8] evaluations that interface with the overall review of the containment subcompartments.

1. The Mechanical Engineering Branch (EMEB)[9] ~~and the Structural Engineering Branch (SEB)~~, as part of ~~their~~its primary review responsibility for SRP Section~~s~~ 3.6.2, ~~and 3.8.3, respectively,~~will review the break locations and dynamic effects of postulated pipe ruptures, and[10] the mechanical ~~and structural~~ design of movable and stationary devices provided for vent flow control in containment subcompartments.[11]

2. The Civil Engineering and Geosciences Branch (ECGB)[12], as part of its primary review responsibility for SRP Section 3.8.3, will review the structural design of movable and stationary devices provided for vent flow control in containment subcompartments.[13]

3. The Materials and Chemical Engineering Branch (EMCB) reviews those applications that propose to exclude dynamic effects of pipe ruptures, including localized pressurization effects and loads on component supports, as part of its primary review responsibility for SRP Section 3.6.3 (later).[14]

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria and their methods of application~~s~~ are contained in the referenced SRP sections of the corresponding primary branch~~identified as the primary review responsibility of those branches~~.[15]

II. ACCEPTANCE CRITERIA

The acceptance criteria given below apply to the design and functional capability of subcompartments in the primary containment. SCSB[16] accepts the containment design of subcompartments if the relevant requirements of General Design Criteria 4 and 50 are complied with. The relevant requirements are as follows:

A. General Design Criterion 4, as it relates to the environmental and missile protection provided to assure that structures, systems and components important to safety are~~be~~[17] designed to accommodate the dynamic effects (e.g., effects of missiles, pipe whipping, and discharging fluids that may result from equipment failures) that may occur during plant normal operations or during an accident.

B. General Design Criterion 50, as it relates to the subcompartments being designed with sufficient margin to prevent fracture of the structure due to pressure differential across the walls of the subcompartment. In meeting the requirements of GDC 50, the following specific criterion or criteria that pertain to the design and functional capability of containment subcompartments are used as indicated below:

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

   Another model that is also acceptable, for a restricted class of subcompartments, involves simplifying the air model outlined above. For this model, 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. However, the adequacy of this simplified model for subcompartments having primarily subsonic flow through the vents has not been established.

2. Subcompartment nodalization schemes should be chosen such that there is no substantial pressure gradient within a node, i.e., the nodalization scheme should be verified by a sensitivity study that includes increasing the number of nodes until the peak calculated pressures converge to small resultant changes. The guideline of Section 3.2 of NUREG-0609 (Reference 27)[18] should be followed and a nodalization sensitivity study should be performed which includes consideration of spatial pressure variation, e.g., pressure variations circumferentially, axially and radially within the subcompartment, for use in calculating the transient forces and moments acting on components.

3. If vent flow paths are used which 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 design certification[19] stage that will support this analysis.

   c. In meeting the requirements of GDC 4 the effects of missiles that may be generated during the transient should be considered in the safety analysis.

4. The vent flow behavior through all flow paths within the nodalized compartment model should be based on a homogeneous mixture in thermal equilibrium, with

the assumption of 100% 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" (Reference~~. 16~~13)[20] with a multiplier of 0.6 for water-steam mixtures, and the thermal homogeneous equilibrium model for air-steam-water mixtures.

5. At the construction permit or design certification[21] stage, a factor of 1.4 should be applied to the peak differential pressure calculated in a manner found acceptable to the SCSB[22] for the subcompartment, structure and the enclosed components, for use in the design of the structure and the component supports. At the operating license stage, 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 or design certification[23] stage. However, improvements in the analytical models or changes in the as-built subcompartment may affect the available margin.

<u>Technical Rationale:</u>[24]

The technical rationale for application of the above acceptance criteria to PWR dry containments is discussed in the following paragraphs:

1. GDC 4 requires that structures, systems, and components important to safety be designed to withstand the environmental conditions and dynamic effects associated with normal operations, maintenance, testing, and postulated accidents. GDC 4 allows dynamic effects associated with postulated pipe ruptures to be excluded from the design basis when analyses reviewed and approved by the staff demonstrate that the probability of fluid system piping rupture is extremely low. Demonstration of extremely low probability pipe rupture requires fracture mechanics analysis that evaluates the stability of postulated through-wall flaws in piping and the ability to detect leakage through a flaw before the flaw could grow 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 rupture in the design basis of SSC, the staff will continue to require consideration of the global effects of postulated pipe ruptures for the design of subcompartment enclosures since 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 GDC 4 will help ensure that the structural integrity of containment subcompartments is maintained and that the containment structure and systems are protected from the effects of a high energy line break.

2. GDC 50 requires the containment structure and associated heat removal system to be designed with margin to accommodate any loss-of-coolant accident such that the containment design leak rate is not exceeded. A loss-of-coolant accident potentially causes the greatest pressure surge and release of fission products when compared to any other accident. Since it is the most severe challenge expected, containment and its subcompartments must be designed to definitively withstand this accident. Providing

design margin will assure that the design can meet all postulated accidents regardless of unanticipated factors. Following GDC 50 will provide assurance that the structural integrity of containment subcompartments is maintained and that the containment structure and systems are protected from the effects of a subcomaprtment high energy line break.

III. REVIEW PROCEDURES

The procedures described below are followed for the subcompartment analysis review. 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 or by adopting the results of previous reviews of plants with essentially the same subcompartment and high pressure piping design.

Upon request from the primary reviewer, the other 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~~[25] is complete.

The SCSB[26] may perform confirmatory analyses of the blowdown mass and energy profiles within a subcompartment. The analysis is done using the RELAP-4 computer program (Reference ~~15~~12)[27] or the COMPARE computer program (Reference ~~14~~11)[28]. 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 confirm that an appropriate break location has been considered in this analysis.

The SCSB 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 SCSB[29] reviews the analysis and testing programs that substantiate their use. The EMEB[30] and ~~SEB~~ECGB[31] will evaluate the mechanical and structural design of such flow control devices as part of their review responsibility under SRP Sections 3.6.2 and 3.8.3.

The SCSB reviews the nodalization of each subcompartment to determine the adequacy of the calculational model. As necessary, SCSB[32] performs iterative nodalization studies for subcompartments to confirm that sufficient nodes have been included in the model.

The SCSB[33] compares the initial subcompartment air pressure, temperature, and humidity conditions to the criteria given in subsection II, above, to assure that conservative conditions were selected.

The SCSB[34] reviews 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.

Using the nodalization of each subcompartment as specified in the safety analysis report, the SCSB 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 as well as the flow regime. At the present time, the two programs used by the SCSB[35] are RELAP-4 ~~(Ref. 15)~~and COMPARE~~(Ref. 14)~~.[36]

At the construction permit or design certification[37] stage, the SCSB[38] will ascertain that the subcompartment design procedures include appropriate margins above the calculated values, as given in subsection II, above.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[39]

IV. EVALUATION FINDINGS

The conclusions reached on completion of the review of this SRP 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.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[40] 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.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[41]

VI. REFERENCES

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

SRP Draft Section 6.2.1.2
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
2.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
3.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
4.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
5.	SRP-UDP format item, Metrication policy implementation	The existing units of ft^{-1} for loss coefficients and inertia terms was converted to m^{-1} using the guidance of Federal Standard 376B. Since this is a simple change of a general reference to units (no numerical values involved) no metrication documentation was created.
6.	SRP-UDP format item	Added "Review Interfaces" heading to Areas of Review. Reformatted existing description of review interfaces in numbered format to describe how SCSB reviews aspects of Subcompartment Analysis under other SRP sections and how other branches support the review.
7.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
8.	SRP-UDP format item	Changed "branch" to "branches'" for consistency with SRP-UDP guidance.
9.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for SRP Section 3.6.2.
10.	Editorial	GDC 4 and the analysis of pipe ruptures are included in the scope of the existing SRP Section. The Review Interface with SRP Section 3.6.2 was revised to be more complete with regard to the EMEB's responsibilities for review of pipe ruptures and related dynamic effects, including pressurization effects.
11.	SRP-UDP format item	Review interfaces were split into separate items for separate PRBs and SRP sections as recommended in the SRP-UDP guidance.
12.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for SRP Section 3.8.3.
13.	SRP-UDP format item	Review interfaces were split into separate items for separate PRBs and SRP sections as recommended in the SRP-UDP guidance.

Item	Source	Description
14.	**Potential Impact # 21753**	Added a Review Interface with SRP Section 3.6.3 regarding review of leak-before-break analyses as they may apply to containment subcompartment analyses. Although leak-before-break cannot be used to eliminate global pressurization effects on containment, certain localized effects may be excluded. Therefore, it is appropriate to include an interface with SRP Section 3.6.3.
15.	SRP-UDP format item	Revised the last phrase of the closing statement for the Review Interface section to read "in the referenced SRP sections of the corresponding primary branch" for consistency with SRP-UDP guidance.
16.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Sections.
17.	Editorial	"Be" was changed to "are" to clarify and correct the wording of the sentence.
18.	SRP-UDP format item	Format change to make the citation of references consistent with the SRP-UDP required format.
19.	10 CFR 52 applicability related change	Added "or design certification" to specify that review of vent flow path test data or proposed testing program is applicable at the design certification stage.
20.	SRP-UDP format item/Unverified reference	Format change to make the citation of references consistent with the SRP-UDP required format. The reference number was changed due to revisions in the Reference section of SRP 6.2.1. In addition, this reference, which is cited in Acceptance Criteria as an acceptable code for vent flow correlations for containment subcompartments, has not been verified as the most current reference in use by the staff.
21.	**Integrated Impact #318**	Specific criterion 5 in Acceptance Criteria was changed to specify peak differential pressure design margin applicable to design certification applicants.
22.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
23.	**Integrated Impact #318**	Specific criterion 5 in Acceptance Criteria was changed to specify peak differential pressure design margin applicable to design certification applicants.
24.	SRP-UDP format item, Develop Technical Rationale	Added Technical Rationale for GDC's 4 and 50. Technical Rationale is a new SRP-UDP format item.
25.	Editorial	The word "procedure" was deleted since the reviewer is completing a review and not a review procedure.
26.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.

Item	Source	Description
27.	SRP-UDP format item/Unverified reference	Revised the reference number due to revisions in the Reference section of SRP 6.2.1. This reference, which is cited in Review Procedures as an acceptable code for NRC analysis of containment subcompartment response to a high energy line break, has not been verified as the most current reference in use by the staff.
28.	SRP-UDP format item/Unverified reference	Revised the reference number due to revisions in the Reference section of SRP 6.2.1. This reference, which is cited in Review Procedures as an acceptable code for NRC analysis of containment subcompartment response to a high energy line break, has not been verified as the most current reference in use by the staff. In section 6.2.1.7 of the ABWR FSER, the staff discussed use of the computer code COMPARE MOD1A to conduct check calculations (see PI 24399). However, this is a different version of the computer code than is currently cited in SRP 6.2.1.2.
29.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section (2 identical changes in this paragraph).
30.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for SRP Section 3.6.2.
31.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for SRP Section 3.8.3.
32.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section (2 identical changes in this paragraph).
33.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
34.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section.
35.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Section (2 identical changes in this paragraph).
36.	SRP-UDP format item	Format change to make the citation of references consistent with the SRP-UDP required format.
37.	**Integrated Impact #318**	Section III Review Procedures was changed to specify that subcompartment pressure design margin is applicable to design certification applicants.
38.	Current PRB names and abbreviations	Editorial change to reflect current PRB name and responsibility for this SRP Sections.

Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
39.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
40.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
41.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.

SRP Draft Section 6.2.1.2
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
318	Consider modifying Acceptance Criteria and Review Procedures to make construction permit stage design margin requirements applicable to design certification applicants.	Section II Acceptance Criteria, specific criterion 5. Section III Review Procedures.