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UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

DG 1203 on Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design Basis Pressure (For New Reactors)

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Category 2 Public Meeting
October, 8, 2009
Rockville, MD

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Outline:

- DG 1203 Timeline
- Major Revisions
- Comments Categories
- Description of Revised Draft Guide (DG) and Resolution to Public Comments.

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DG 1203 Timeline

- Dec 2008 – Issued for public comments
- Feb 2009 – Received public comments
- DG revision with NRC working group and BNL
- Oct 2009 – Category 2 public meeting
- Nov 2009 – Interoffice concurrence
- Feb 2010 – ACRS briefing
- Mar 2010 – Regulatory Guide (RG) publication

Major Revisions

- The DG scope is for new light water reactor designs
- Clarification of the DG purpose and relation to existing requirements and guidance documents.
- Severe accident performance goal related to SECY 93-087 and related SRM
  - Approach to identify the <u>more likely severe accident challenges.</u>
  - Additional criteria for the period following the initial 24 hours after the onset of core damage.
- Removal of Regulatory Position (RP) 4, “Containment Fragility under Pressure Loads”
  - Complex item that may be addressed first in a NUREG report or a standard.

Comments Categories

- 38 comments including general comment in the NEI cover letter:

Purpose	6
Applicability	11
Methodology	3
Acceptable Analysis Codes	2
Definitions	1
Limitations	10
Criteria	5

- Comments by Regulatory Position (RP):

RP 1	4
RP 2	1
RP 3	7
RP 4	12
RP 1 and RP 3	2
RP 1 and RP 4	2
RP 3 and RP 4	1
Other	9

Objective:

- To provide methods acceptable to the NRC staff to satisfy requirements set forth in:
  - 52.47(a)(9), 52.79(a)(41)
  - 52.47(a)(12), 52.79(a)(8), 50.44(c)5
  - 52.47(a)(23), 52.79(a)(38).
- These methods relate to the evaluation of containment structural integrity related to:
  - Internal pressure above the design pressure (RP 1)
  - Combustible gas control (RP 2)
  - Commission's severe accident performance goal (RP 3)

Regulatory Position 1: Prediction of Containment Internal Pressure Capacity above Design Basis Pressure

- **Regulations:**
  - **52.47(a)(9)** "*For applications for light-watercooled nuclear power plants, an evaluation of the standard plant design against the Standard Review Plan (SRP) revision in effect 6 months before the docket date of the application…*"
  - **52.79(a)(41)** "*For applications for light-water-cooled nuclear power plant combined licenses, an evaluation of the facility against the Standard Review Plan (SRP) revision in effect 6 months before the docket date of the application…*"
- **Relevant SRP sections**
  - 3.8.1 and 3.8.2, SRP Acceptance Criteria 4.K and 4.D, respectively.

Regulatory Position 1: (Cont.)

- **Purpose:** to provide an acceptable method to obtain a measure of safety margin for the containment structure, above the design pressure.
- **Items Addressed:**
  - Staff expectations regarding the use of a nonlinear finite element analysis to evaluate the containment response
  - Staff expectations regarding the use of a "Simplified Method"
    - Strain limits specified for the evaluation
    - These limits incorporate reductions that account for strain risers in actual containments that are more severe than those in the models tested (NUREG/CR-6906) and for results in NUREG/CR-6810 and NUREG/CR-6809.
    - The positions are consistent with criteria in SRP sections 3.8.1 and 3.8.2 with the addition of a position regarding verification of concrete shear and axial compression failures.
  - Information to be submitted in the FSAR and in which sections of the FSAR.

Resolution of Public Comments on RP 1:

1. **Comment:** "No leakage criteria is identified for C.1 item k."

   Staff Response: Currently there is no regulation or guidance to specify leakage criteria for this purpose. In past licensing review process, the applicants provided their acceptance criteria which were reviewed on a case-by case basis. Presently, it is more productive to continue to review criteria presented by the applicant on a case-by case basis rather than establishing leakage criteria. Therefore, no change was made.

Resolution of Public Comments on RP 1:

2. **Comment:** "The effects of corrosion are not specified for inclusion in the ultimate pressure capability calculation."

   Staff Response: The scope of the DG is for new light water reactor designs. In general, industry practice for as-built containments has been to inspect and monitor for degradations and to repair them when they may affect safety. Therefore, no change was made.

Resolution of Public Comments on RP 1:

3. **Comment:** "Why is Service Level C selected as the criteria for use in assessing severe accident challenges (see P.6)? Service Level C is not the appropriate realistic ultimate pressure capability criteria to be used. This introduces unacceptable conservatisms. This is demonstrated by the extensive testing of containment structures (e.g., NUREG/CR-6906)."

   Staff Response: Service Level C was not given as a criterion for RP 1. Discussion related to level C limits has been removed from the text for RP 1.

Resolution of Public Comments on RP 1:

4. **Comment:** This comment addresses the acceptable membrane strains in steel and concrete containments to define the ultimate pressure capacity. The comment also addresses leakage failures as opposed to catastrophic failures for concrete containments.

   Staff Response: These strain limits are for use with an alternative "Simplified Method" to the more rigorous nonlinear FEM of analysis. The strain limits incorporate reductions to account for strain risers in actual containments that are more severe than those in the models tested and for results in NUREG/CR-6810 and NUREG/CR-6809. Leakage failures are addressed in comment 1 (slide 9).

Regulatory Position 2: Combustible Gas Control Inside Containment

- **Regulations:**
  - **52.47(a)(12)** *"An analysis and description of the equipment and systems for combustible gas control as required by 10 CFR 50.44;"*
  - **52.79(a)(8)** *"An analysis and description of the equipment and systems for combustible gas control as required by § 50.44 of this chapter;"*
  - **50.44(c)5** "*Structural analysis. An applicant must perform an analysis that demonstrates containment structural integrity… The analysis must address an accident that releases hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by hydrogen burning…"*
- **Purpose:** to provide an acceptable method to evaluate containment structural integrity to pressure loadings associated with hydrogen generation due to the reaction between fuel cladding and the water coolant.

Regulatory Position 2: (Cont.)

- RP 5 of Regulatory Guide 1.7 already provides acceptance criteria to meet requirements in 10 CFR 50.44 that pertain to the structural integrity of steel and concrete containments.
  - Criteria are based on the Service Level C requirements of the ASME Code for steel containments and on the Factored Load Category requirements of the ASME code for concrete containments.
- The load combination for this case is the dead load and the higher of the following:
    - Pressure arising from fuel cladding-water reaction, hydrogen burning, and post accident inerting (if applicable), or
    - 45 psig.
- This DG provides technical guidance for implementing RP 5 in RG 1.7 to evaluate the containment structural integrity for satisfying 10 CFR 50.44.
  - Specifically, it says that a finite element model as described in RP 1 of this DG, with some limitations, is an acceptable method to evaluate the containment structural integrity under the combination of dead load and internal pressures indicated above.

Resolution of Public Comments on RP 2:

1. **Comment:** "What's the purpose of 45 psig (p. 10)?"

- **Staff Response:** The 45 psig is from regulatory positions: 5 of RG 1.7; 1.2.3.3 of RG 1.57; and 5.B.3 of RG 1.136.

Regulatory Position 3: Commission's Severe Accident Performance Goal

- **Regulations (for DC and COL applications, respectively):**
  - 52.47(a)(23) "*For light-water reactor designs, a description and analysis of design features for the prevention and mitigation of severe accidents …*"
  - 52.79(a)(38) "*For light-water reactor designs, a description and analysis of design features for the prevention and mitigation of severe accidents …*"
- **Purpose:** to provide an acceptable method to meet Commission's deterministic performance goals related to the evaluation of the containment structural integrity under pressure loadings associated with the "more likely severe accident challenges".
- Section C.I.19.8 of RG 1.206 provides guidance related to requirements for the prevention and mitigation of severe accidents:
  - *"The applicant should provide a description and analysis of the design features to prevent and mitigate severe accidents, in accordance with the requirements in 10 CFR 52.47(23) or 10 CFR 52.79(a)(38), for a DC or a COL application, respectively. This review should specifically address the issues identified in SECY-90-016 and SECY-93-087, which the Commission approved in related SRMs dated June 26, 1990, and July 21, 1993, respectively, for prevention (…) and mitigation (…)."*

Regulatory Position 3: Commission's Severe Accident Performance Goal (cont.)

- SECY-90-016 and SECY-93-087 and related SRMs established performance goals for containment structures in nuclear power plants under severe accidents.
- SRM (July 21, 1993) to SECY-93-087 states:
  - *"The containment should maintain its role as a reliable, leak-tight barrier (for example, by ensuring that containment stresses do not exceed ASME Service Level C limits for metal containments, or Factored Load Category for concrete containments) for approximately 24 hours following the onset of core damage under the more likely severe accident challenges and, following this period, the containment should continue to provide a barrier against the uncontrolled release of fission products."*
- Key items:
  - Identification of more likely severe accident challenges
  - Criteria for structural integrity evaluation of the containment for the period after the initial 24 hours following the onset of core damage as it relates to the ability of the containment to continue to provide a barrier against the uncontrolled release of fission products.

More Likely Severe Accident Challenges

- Selection of accident sequences for consideration:
  - *"The applicant provides the technical basis for the identification of the more likely severe accident challenges to be reviewed by the staff on a case-by-case basis. An example of an acceptable way to identify the more likely severe accident challenges is, to consider the sequences or plant damage states, which, when ordered by % contribution, represent 90% or more of the core damage frequency."*
- Pressure-temperature demands
  - Select physically reasonable enveloping pressure-temperature demands from the identified sequences.
    - These demands define the deterministic loads for the structural analysis.
    - For concrete, it is generally acceptable to analyze the containment for the sequence or damage state with the highest pressure load and its co-existing temperature loading

Period Following Initial 24 hours after the Onset of Core Damage:

- "…the containment should continue to provide a barrier against the uncontrolled release of fission products."
- Acceptable ways for meeting the performance goal:
  - The maximum pressure/temperature demands following the initial 24-hour period is enveloped by the maximum pressure/temperature demands during the initial 24-hour period; or
  - The containment response under the maximum pressure/temperature following the initial 24-hour period meets applicable Level C or Factored Load acceptance criteria (as in the case of the first 24 hour period); or
  - The calculated release for the more likely severe accident challenges, following the initial 24 hour period, meets site-specific design criteria for fission product released from the containment, in accordance with the requirements of 10 CFR 100.21 and 10 CFR 50.34; or
  - Another alternative method if adequate justification is provided.
- For the evaluations to be conducted for the two time periods under consideration, the DG recommends using a finite element model such as that described in Regulatory Position 1.

Resolution of Public Comments on RP 3:

1. **Comment:** The severe accident profile to be used in the assessment of containment capability is ill-defined and leaves this open to interpretation and broad expectation. A consensus group of NRC and industry experts would provide valuable guidance regarding the formulation of the criteria to be used in selecting the severe accident profile.

   Staff Response: Selection of the severe accident profile is addressed in the revised DG (see slide 18 entitled "more likely severe accident challenges").

Resolution of Public Comments on RP 3:

2. **Comment:** Acceptable methods for the calculation of imposed severe accident loads requires additional description. Specifically, it is desirable to provide a list of acceptable severe accident analysis codes that could be used to support the severe accident challenges to be evaluated in the structural analysis.

   In addition, the criteria to be used in selecting the "more likely severe accident challenges" is necessary.

   Similarly, guidance on an acceptable approach to the consideration of dynamic loads caused by excessive pool levels during containment flooding is necessary for BWRs.

   Staff Response:

   - Methods for the calculation of imposed severe accident loads are not in the scope of this DG, which addresses structural integrity aspects of the containment.
   - Selection of the "more likely severe accident challenges" is addressed in the revised DG (see slide 18).
   - The DG states that potential structural dynamic amplification effects caused by the pressure transients for the severe accident events, if significant, should be included in calculating the response of the containment.

Resolution of Public Comments on RP 3:

3. **Comment:** Computer analysis related to severe accident load calculations is required in Section C.3 to ensure that the ultimate pressure and temperature capability of the containment meets the intent of the Regulatory Guide. The basis for determining the acceptability of the codes used in calculating the severe accident challenges would appear to be in need of definition. An effective Regulatory Guide must provide an acceptable means to satisfy the calculation requirements used to impose the loads. Specifically, the use of MAAP by a qualified analyst with a verified parameter file should be listed as an acceptable example. Alternatively, a consensus group of NRC and industry experts would provide valuable guidance regarding the formulation of the criteria to be used in selecting the severe accident profile.

   Staff Response:
   - Methods for the calculation of imposed severe accident loads are not in the scope of this DG, which addresses the structural integrity aspects of the containment.
   - Selection of the "more likely severe accident challenges" is addressed in the revised DG (see slide 18).

Resolution of Public Comments on RP 3:

4. **Comment:** Several terms appear to be in need of definition to effectively use the proposed Regulatory Guide and these include the following:
   - "More Likely Severe Accident Challenges" is not defined. This leads to an open-ended analysis criteria.
   - Containment should maintain "leak-tight barrier" for 24 hours. ("Leak-tight" is not defined.)
   - Containment should continue to provide a barrier against "uncontrolled release" of fission products after 24 hours. ("Uncontrolled release" is not defined.)
   - "Design Basis Accident Temperature" is not defined (See p.7 of DG-1203).

   Staff Response:
   - Selection of the "more likely severe accident challenges" is addressed in the revised DG (see slide 18).
   - In agreement with the Commission's performance goal the DG guidance is that a reliable "leak-tight" barrier is provided by ensuring that containment stresses do not exceed ASME Service Level C limits for metal containments, or Factored Load Category limits for concrete containments.
   - The revised DG provides guidance on how to meet the Commission's performance goal related to the "uncontrollable release" of fission products (see slide 19) after 24 hours following the onset of core damage.
   - The "design basis accident temperature" is the temperature used in the design of the containment for the design basis loss-of-coolant accident (LOCA) in agreement with General Design Criteria 50 in App. A of 10 CFR part 50.

Resolution of Public Comments on RP 3:

5. **Comment:** Section C.3: For initial 24 hours, linear elastic material properties may be used. This does not appear to allow for use of inelastic material evaluations in a realistic ultimate pressure/temperature calculation.

   Staff Response: RP 3 for the initial 24-hour period is not intended to calculate the ultimate pressure/temperature capacity of containment. It is intended to show that for the "more likely severe accident challenges" a "leak tight barrier" is provided if Service Level C limits in the ASME Code are satisfied for steel containments and the Factored Load Category limits are satisfied for concrete containments (per the Commission's performance goals).

   In accordance with the ASME Code, Service Level C and Factored Load Category criteria are verified using linear elastic analysis methods.

Resolution of Public Comments on RP 3:

6. **Comment:** The Regulatory Guide does not address the following that may be critical:

   Challenges

   - Dynamic pressure loads (e.g., pressure suppression containments)
   - Missiles (Internal and External)
   - Direct interaction of containment boundary by debris
   - Containment bypass

   Staff Response: Dynamic design pressure loadings, missiles, direct interaction of containment boundary with debris and containment bypass are not in the scope of the DG.

   For dynamic pressure loads see the response to Comment 1 for RP 1 and RP 3 (slide 27).

Resolution of Public Comments on RP 3:

7. **Comment:** What is the meaning of limiting the steel containment analysis in C.3 to the use of linear elastic material properties? This would appear to result in unacceptably large conservatisms in the analytic results.

   Staff Response: Refer to staff response to comment 5, in this section (slide 24).

Resolution of Public Comments on RP 1 and 3:

1. **Comment:** Some limitations that should be stated more clearly include the following:

   Requirements for dynamic load effects:
   - Dynamic effects DO NOT need to be considered (page 7)
   - Dynamic effects DO need to be considered (page 12 a(2), page 8 Item l)).

   Staff Response: Agreed. The revised text in the draft reads as follows:
   - **For RP 1:** For the purpose of estimating the safety margin above the design-basis accident pressure, static analysis is acceptable. However, if dynamic response effects are important, the static pressure capacity may need to be reduced to account for such effects. One acceptable approach is a nonlinear dynamic analysis. Alternative approaches provided by the applicant will be reviewed on a case by case basis.
   - **For RP 3:** The potential structural dynamic amplification effects caused by the pressure transients for the severe accident events, if significant, should be included in calculating the response of the containment.

Resolution of Public Comments on RP 1 and 3:

2. **Comment:** Leakage acceptance criteria are to be provided by the Licensee to the NRC for review. This remains open-ended.

Staff Response:

- Refer to staff response to comment 1 in RP1 (slide 9).
- RP 3 states that the goal for a “leak-tight barrier” is met by complying with Service Level C limits for steel containments and Factored Load Category limits for concrete containments.
- RP 3 also provides guidance to meet the goal for “uncontrollable release of fission products” (slide 19).

Resolution of Public Comments on RP 1 and RP 4:

1. **Comment:** What is the purpose of incorporating conservatisms into the analysis and performance goals? This is supposed to be a "realistic" method and performance goal for containments for use within a PRA. Dictating the use of Service Level C as the criteria for the Containment Ultimate Pressure and Temperature may introduce significant conservatisms that are inappropriate for the realistic PRA evaluation.

   Staff Response:

   – Agreed. The strain limits in RP 1 include reductions from the test results that account for strain risers in actual containments that are more severe than those in all the models tested, and for results in NUREG/CR-6810 and NUREG/CR-6809 (see slide 12).

   – RP 1 to RP 3 are not for use within a PRA. Only RP 4 was intended for use in a PRA. Note that RP 4 has been removed from the DG.

   – Note that the use of Service Level C criteria is not related to containment ultimate pressure capacity and temperature but only to RP 2 and RP 3 (see slide 11).

Resolution of Public Comments on RP 1 and 4:

2. **Comment:** There is a conflict in that Section C.1 allows the use of 2D axisymmetric or partial finite element models, but Section C.4 Item (g) appears to contradict that allowance.

   Staff Response: The Regulatory Positions in the DG provide guidance criteria for use in separate evaluations to meet different regulations and NRC regulatory guidance. Note that although RP 2 to 4 referenced the analysis techniques described in RP 1, exceptions/limitations were taken to make it specific to the cases discussed in each RP. In this specific case, any perceived contradiction is eliminated given that RP 4 has been removed from the DG.

Resolution of Public Comments on RP 3 and 4:

1. **Comment:** The deterministic goals in C.3 for containment capability up to 24 hours and then beyond 24 hours appear to be too ill-defined at the present time and should be better formulated. A consensus group of NRC and industry experts would provide valuable guidance regarding the formulation of C.3.

   The Section B discussion is not adequately focused on the Section C Regulatory position. In addition, the focus of the DG-1203 is stated to be on Design Engineering and System Engineering. However, there is extensive impact on the PRA, both in required analysis and on the effects of the analysis on the remainder of the PRA evaluation.

   Staff Response:

   – The revised RP 3 provides an approach to identify the "more likely severe accident challenges" (see slide 18) and guidance on how to meet Commission's performance goals up to 24 hours and beyond 24 hours (see slide 19).
   – The scope of the DG is on deterministic methods to evaluate containment structural integrity under pressure loads above design basis pressure. PRA aspects including containment fragility are not within the scope of the revised DG.

Anticipated Activities

Final Interoffice Concurrence	November 2009
Brief ACRS	February 2010
Publish Final Regulatory Guide	March 2010