

# Proposed - For Interim Use and Comment



## U.S. NUCLEAR REGULATORY COMMISSION DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER™ iPWR DESIGN

### 3.5.1.1 INTERNALLY-GENERATED MISSILES (OUTSIDE CONTAINMENT)

#### REVIEW RESPONSIBILITIES

**Primary** - Organization responsible for review of the plant design for protection of structures, systems, and components from internal and external hazards

**Secondary** - None

#### I. AREAS OF REVIEW

Title 10 of the *Code of Federal Regulations* (CFR), Part 50, Appendix A, General Design Criterion (GDC) 4 requires that all structures, systems, and components (SSCs) important to safety shall be designed 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. GDC 4 also requires that such SSCs are 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 unit. This section of the staff's review includes protection of such SSCs from internally-generated missiles from component overspeed failures, missiles that could originate from high-energy fluid systems failures, and missiles caused by or as a consequence of gravitational effects.

All safety-related and certain risk-significant SSCs outside containment are subject to missile protection. An SSC may be classified as:

- Safety-related risk-significant;
- Safety-related non-risk-significant;
- Nonsafety-related risk-significant; or
- Nonsafety-related non-risk significant.

The mPower™ application will include the classification of SSCs, a list of risk-significant SSCs, and a list of regulatory treatment of non-safety systems (RTNSS) equipment. Based on this information, the staff's review will use DSRS Section 3.2, and SRP Sections 17.4 and 19.3 to confirm the determination of the safety-related and risk-significant SSCs. If the SSC belongs in one of the first two classifications above or if it is determined as part of the SRP 19.3 "Augmented Design Standard" review that the SSC is RTNSS "B", the review described in this DSRS Section 3.5.1.1 is applied (see Review Procedure 2 below). For the purpose of brevity in this section, the first two categories above and the RTNSS "B" SSCs will be designated as "SSCs subject to missile protection." SSCs in the 4<sup>th</sup> classification above are not subject to missile protection.

The specific areas of review are as follows:

1. Protection from internally-generated missiles (outside containment) including identification of structures, systems or portions of systems, components and the methods of protection provided. Determination of the potential of pressurized components and systems for generating missiles such as valve bonnets and hardware-retaining bolts, relief valve parts, turbine blades, and instrument wells. Determination of the potential of high-speed rotating machinery for generating missiles from component overspeed or such failures as the pump itself (from seizure), pump or component parts, and rotating segments (e.g., impellers and fan blades).
2. Internal missile effects of nonsafety-related SSCs that could affect an intended safety function of SSCs subject to missile protection.
3. Plausible secondary missiles generated as a result of impact with primary missiles.
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 SSCs related to this DSRS section in accordance with DSRS 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 DSRS 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 DSRS Section 14.3.
5. COL Information Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL information 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 Information 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 DSRS sections interface with this section as follows:

1. Review of the acceptability of the analytical procedures and criteria for structures or barriers that protect the essential systems and safety-related components from internally-generated missiles is performed under DSRS Section 3.5.3, "Barrier Design Procedures." The results of this review can be utilized to complete the overall evaluation of the protection against internally-generated missiles.
2. Review of dynamic effects associated with the postulated rupture of piping inside the containment, is performed under DSRS Section 3.6.2, "Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping." Typically included in DSRS Section 3.6.2 is the review of any high-energy line spatial separation analyses by an applicant. The results of this review can be utilized to complete the overall evaluation of the protection against internally-generated missiles.

3. Review of turbine generator analyses for turbine missiles is performed under DSRS Section 3.5.1.3.
4. Review of the regulatory treatment of nonsafety systems related to augmented design standards of missile protection for nonsafety-related risk significant SSCs, is performed under Standard Review Plan (SRP) Section 19.3.
5. Review of the classification of safety-related SSCs is performed under DSRS Section 3.2.2.

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

## II. ACCEPTANCE CRITERIA

### Requirements

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

1. 10 CFR Part 50, Appendix A, GDC 4 as it relates to the design of the SSCs important to safety if the design affords protection from the internally-generated missile that may result from equipment failure.
2. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAACs that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the DC has been constructed and will be operated in conformity with the DC, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulation Commission's (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 COL, the provisions of the AEA, and the NRC's regulations.

### DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth below. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. Identifying the differences between this DSRS section and the design features, analytical techniques, and procedural measures proposed for the facility, and discussing how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria, is sufficient to meet the intent of 10 CFR 52.47(a)(9), "Contents of applications; technical information." The same approach may be used to meet the requirements of 10 CFR 52.79(a)(41) for COL applications.

The design of the SSCs subject to missile protection are acceptable if the integrated design affords protection from the internally-generated missiles (outside containment) that may result

from equipment failure and from events and conditions outside the nuclear unit, in order to maintain their safety functions in accordance with GDC 4. Acceptance is based on the design meeting the guidance as described in Regulatory Guide (RG) 1.115, "Protection Against Turbine Missiles," as related to the protection of SSCs important to safety from the effects of turbine missiles.

1. The applicant's statistical significance of an identified missile can be evaluated by a probability analysis. Its statistical significance is determined by calculating the probability of missile occurrence. If this probability is less than  $10^{-7}$  per year, the missile is not considered statistically significant. If the probability of occurrence is greater than  $10^{-7}$  per year, the probability of impact on a significant target is determined. If the product of these two probabilities is less than  $10^{-7}$  per year, the missile is not considered statistically significant. If the product is greater than  $10^{-7}$  per year, the probability of significant damage is determined. If the combined probability (product of all three) is less than  $10^{-7}$  per year, the missile is not considered statistically significant. If the combined probability is greater than  $10^{-7}$  per year, missile protection of SSCs subject to missile protection, and of nonsafety-related SSCs whose failure could affect an intended safety function of the safety related SSCs, should be provided by one or more of the six methods listed below.
2. Missile protection for SSCs subject to missile protection is adequate if provided by one or more of the following methods: (1) locating the system or component in a missile-proof structure, (2) separating redundant systems or components for the missile path or range, (3) providing local shields and barriers for systems and components, (4) designing the equipment to withstand the impact of the most damaging missile, (5) providing design features to prevent the generation of missiles, or (6) orienting missile sources to prevent missiles from striking equipment important to safety.

Where barriers are used as a method of protecting SSCs from internal missiles, the design of the barriers is acceptable if it meets the guidance of RG 1.115 Position C.3.

Components within one train of a system with redundant trains need not be protected from missiles originating from the same train.

### 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. 10 CFR Part 50, Appendix A, GDC 4 requires the protection of SSCs important to safety from dynamic effects, including those of internally-generated missiles. The failure of such internal facility equipment as pressurized components, high-energy piping, and rotating equipment outside the containment may generate missiles. An internally-generated missile is a dynamic effect of such failures and its impact on SSCs important to safety must be evaluated. RG 1.115 describes methods acceptable to the staff for protection of SSCs important to safety from the effects of missiles resulting from turbine failure. Cumulative failure data for conventional plants indicate that the protection of SSCs important to safety from the effects of missiles is an appropriate safety consideration. Protecting SSCs important to safety from the effects of internally-generated missiles ensures the integrity of the reactor coolant pressure boundary, the capability to shut down and maintain the reactor in a shutdown condition, and the capability to prevent significant uncontrolled release of radioactivity.

### III. REVIEW PROCEDURES

These review procedures are based on the identified DSRS 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. In accordance with 10 CFR 52.47(a)(8),(21), and (22), for new reactor license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues that are identified in the version of NUREG-0933 current on the date 6 months before application and that are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding safety evaluation report (SER) section.
2. Review of the effects of internally-generated missiles on structures is a primary responsibility under SRP Section 3.5.3. The first step in the review of SSCs requiring protection against internally-generated missiles is to determine whether the equipment is needed to perform a safety-related function or a risk-significant function. DSRS Section 3.2.2 and SRP Section 19.3 as related to augmented design standards provide guidance on the identification of the SSCs subject to missile protection. The safety functions of the SSCs in the various plant designs are essentially the same; however, the location and arrangement of the SSCs and the methods used may vary depending upon individual design. The reviewer must evaluate variations in plant designs as individual cases. SSCs that perform safety functions or which by virtue of their failure could affect a safety function adversely should be protected from the effects of internally-generated missiles.
3. The information in the DC and COL applications on SSC design bases and criteria, system descriptions and safety evaluations, piping and instrumentation diagrams, station layout drawings, and system and component characteristic and classification tables are reviewed for potential sources of missiles and for SSCs requiring protection to maintain their safety-related and risk significant functions. The reviewer may use failure mode and effect analyses and the results of reviews by other branches (see Review Interfaces) in evaluating SSCs to identify those requiring protection from internally-generated missiles, the origins of possible missiles, and the adequacy of the protection.
4. The reviewer determines whether nonsafety-related SSCs are protected from internally-generated missiles by whether their failure by a missile impact could prevent surrounding SSCs from performing their required safety function.
5. The reviewer determines whether the applicant's procedures, analysis, and design details ensure that pressurized gas bottles will not become missiles capable of damaging SSCs

subject to missile protection to the extent that safety-related and risk significant functions are compromised. The storage and handling of compressed gases at nuclear power plants was studied by Oak Ridge National Laboratory for potential safety hazards. The results of these studies are documented in NUREG/CR-3551.

6. For COL applicants referencing a certified design, the reviewer determines whether adequate protection is included in the design details for pressurized gas bottles and in the details of missile protection features for any SSC outside the scope of the DC.
7. 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. The reviewer should also consider the appropriateness of identified COL information items. The reviewer may identify additional COL Information items; however, to ensure these COL Information 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 or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

For review of both DC and COL applications, DSRS 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 SER. The reviewer also states the bases for those conclusions.

1. The review of possible effects of internally-generated missiles (outside containment) included SSCs whose failure could prevent safe shutdown or cause significant uncontrolled release of radioactivity. The staff's review concluded that the applicant's design bases and criteria for SSCs subject to missile protection necessary to maintain a safe plant shutdown meet the 10 CFR Part 50, Appendix A, GDC 4 requirements for SSCs to be protected from internally-generated missiles (outside containment), because the applicant:
  - A. Has met the guidance in RG 1.115, "Protection Against Turbine Missiles," Position C.3, for the protection of SSCs important to safety from the effects of turbine missiles;
  - B. Has used methods to identify potential sources of internal missiles and demonstrated the adequacy of the protection methods, as reviewed by the staff in this or in previous applications and found acceptable; and
  - C. Has shown that the functions of SSCs subject to missile protection will be protected from internally-generated missiles (outside containment) by individual missile-proof structures, adequate physical separation for redundant systems or

the component of systems, or special localized protective shields or barriers for the systems or components.

2. For those applicants referencing a certified design, the findings will summarize the staff's evaluation of the design details for pressurized gas bottles as well as details of missile protection features for SSCs outside the DC scope.

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 information items relevant to this DSRS 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 DSRS section in performing safety evaluations of mPower™-specific DC, or COL, applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations.

Because of the numerous design differences between the mPower™ and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (Agencywide Documents Access and Management System Accession No. ML102510405), to develop risk-informed licensing review plans for each of the small modular reactor reviews, including the associated pre-application activities, the staff has developed the content of this DSRS section as an alternative method for mPower™-specific DC, or COL submitted pursuant to 10 CFR Part 52 to comply with 10 CFR 52.47(a)(9), "Contents of applications; technical information."

This regulation states, in part, that the application must contain "an evaluation of the standard plant design against the SRP revision in effect 6 months before the docket date of the application." The content of this DSRS section has been accepted as an alternative method for complying with 10 CFR 52.47(a)(9) as long as the mPower™ DCD FSAR does not deviate significantly from the design assumptions made by the NRC staff while preparing this DSRS section. The application must identify and describe all differences between the standard plant design and this DSRS section, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria. If the design assumptions in the DC application deviate significantly from the DSRS, the staff will use the SRP as specified in 10 CFR 52.47(a)(9). Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design assumptions. The same approach may be used to meet the requirements of 10 CFR 52.79(a)(41) for COL applications.

## VI. REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases."

2. RG 1.115, "Protection Against Turbine Missiles."
3. NUREG/CR-3551, "Safety Implications Associated with In-Plant Pressurized Gas Storage and Distribution Systems in Nuclear Power Plants."