

# Proposed - For Interim Use and Comment



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

### 3.4.1 INTERNAL FLOOD PROTECTION FOR ONSITE EQUIPMENT FAILURES

#### REVIEW RESPONSIBILITIES

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

**Secondary** - Organization responsible for hydrology reviews

#### I. AREAS OF REVIEW

The review of the plant internal flood protection includes all structures, systems, and components (SSCs) whose failure could prevent safe shutdown of the plant or result in uncontrolled release of significant radioactivity. The facility design and equipment arrangements presented in the applicant's safety analysis report (SAR) are reviewed with respect to both internal (e.g., pipe break, tank failure) and external (e.g., failure of exterior tanks) causes. The review of external flood protection from natural phenomena (e.g., probable maximum flood, tsunami, etc.) is performed in a separate review as listed in the Review Interfaces subsection of this Design-Specific Review Standard (DSRS) Section.

The plant internal flood protection is required to protect SSCs that are safety-related or risk-significant. An SSC may be classified as:

- Safety-related risk-significant
- Safety-related non-risk-significant
- Nonsafety-related risk-significant
- 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 will review the application according to DSRS Section 3.2, SRP Sections 17.4 and 19.3 to confirm the determination of the safety-related and risk-significant SSCs. If the SSC belongs in 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 is applied. 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 flood protection." SSCs in the 4<sup>th</sup> classification above are not subject to flood protection.

The specific areas of review are as follows:

1. The safety-related or risk-significant SSCs that must be protected against flooding from both external and internal causes.

2. The location of SSCs subject to flood protection relative to the internal flood level in various buildings, rooms, and enclosures that house safety-related or risk-significant SSCs.
3. Possible flow paths from interconnected nonsafety-related areas to buildings, rooms, and enclosures that house SSCs subject to flood protection (e.g., leakage through interconnecting doorways).
4. The adequacy of the isolation of systems and equipment subject to flood protection between redundant trains and from non-safety systems that could be sources of internal flooding.
5. Provisions for protection against possible in-leakage sources, such as non-mechanistic cracks in structures and exterior openings and penetrations in structures located at a lower elevation than the internal flood level.
6. SSCs that could be a potential source of internal flooding (e.g., pipe breaks and cracks, tank and vessel failures, backflow through drains).
7. Design features that will be used to mitigate the effects of internal flooding (e.g., adequate drainage, sump pumps, etc.).
8. Any structure subject to flood protection that are protected from below-grade groundwater seepage by means of a permanent dewatering system.
9. 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.
10. 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 DSRS sections interface with this section as follows:

1. The review of the potential causes of external flooding from natural phenomena and the adequacy of external flood protection is performed under DSRS Sections 2.4.1 through 2.4.14.
2. The review of postulated site flooding parameters is performed under DSRS Section 2.4 and DSRS Section 2.0 for a standard DC application.

3. The review of the acceptability criteria used for the design of structures that should withstand the effects of the design-basis flood is performed under DSRS Section 3.4.2.
4. The review of the adequacy of the technical specifications related to low-water conditions is performed under DSRS Section 2.4.14, and the review of the adequacy of overall plant technical specifications is performed under DSRS Section 16.0.
5. The review of the adequacy of the applicant's listing of SSCs, the failure of which could prevent safe shutdown of the plant, is performed under DSRS Sections 3.2.1 and 3.2.2.
6. The review of the adequacy of the applicant's plant- and/or site-specific probabilistic risk assessment (PRA), including an internal and external flooding analysis, is performed under SRP Chapter 19.0.
7. The review of the environmental effects of a pipe rupture on safety-related systems is performed under SRP Section 3.6.1.
8. The review of the environmental qualifications of mechanical and electrical equipment is performed under DSRS Section 3.11.
9. The review of possible break locations in high and moderate energy systems during normal plant operation and the dynamic effects (e.g., pipe whip, jet impingement) of pipe breaks is performed under DSRS Section 3.6.2.
10. The review of the design of containment internal structures and other safety-related structures is performed under SRP Sections 3.8.3 and 3.8.4, respectively.
11. The review of the instrumentation needed for flood protection, including the adequacy of detectors and alarms necessary to detect rising water levels within structures, and the consequences of flooding on other safety-related instrumentation and electrical equipment is performed under DSRS Chapter 7.
12. The review of flooding effects resulting from a failure of a component or piping of the circulating water system is performed under DSRS Section 10.4.5.
13. The review of equipment and floor drainage system is performed under DSRS Section 9.3.3.
14. The review of risk classification is in SRP Sections 17.4 and 19.3.

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

## II. ACCEPTANCE CRITERIA

### Requirements

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

Acceptability of internal flood protection as described in the applicant's SAR is based on certain requirements of Title 10 of the *Code of Federal Regulations* (CFR), Part 50, Appendix A, General Design Criteria (GDC) and other regulations.

1. The requirements of 10 CFR Part 50, Appendix A, GDC 2 relate to the SSCs important to safety being designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. Meeting the requirements of GDC 2 includes evaluating the effects of flooding from full circumferential failures of non-seismic, moderate-energy piping, which is not considered in DSRS Section 3.6.2.
2. The requirements of 10 CFR Part 50, Appendix A, GDC 4 relate to the SSCs important to safety being 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.
3. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed 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 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 Regulatory Commission's (NRC's) rules and 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 COL, the provisions of the AEA, and the NRC's rules and 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.

1. Guidance acceptable for meeting the seismic design and classification requirements of GDC 2 is found in Regulatory Guide (RG) 1.29, Position C.1 for safety-related SSCs and Position C.2 for nonsafety-related SSCs.
2. The requirements of GDC 4 are met if SSCs, both safety-related and risk-significant, are designed to accommodate the effects of discharged fluid resulting from high and moderate energy line breaks and cracks that are postulated in DSRS Sections 3.6.1 and 3.6.2, as well as from postulated failures of non-seismic and non-tornado protected piping, tanks, and vessels.

#### Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. Compliance with GDC 2 requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. Meeting the requirements of GDC 2 is necessary to ensure that flooding due to failures of non-seismic piping does not affect the ability of the plant to shut down safely and remain in safe shutdown condition. The application of GDC 2 to this DSRS section ensures that consideration is given to full-circumferential ruptures of non-seismic moderate energy piping. These ruptures are not considered in DSRS Section 3.6.2, which only applies to normal conditions, not seismic events. However, internal flooding caused by seismically full-circumferential ruptures should be considered.
2. Compliance with GDC 4 for flood protection requires that SSCs important to safety being 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. Meeting the requirements of GDC 4 ensures that the SSCs important to safety will be appropriately protected from potential flooding from liquid-carrying components in the plant.

### 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 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. An evaluation of the SSCs in the SAR and PRA that are either safety-related or risk-significant and should be protected against floods or flood conditions.
3. An evaluation using the plant arrangement, layout drawings and any other acceptable methods to assess the adequacy of techniques such as enclosures, pumping systems, drains, internal curbs, penetration seals, and watertight doors used to prevent flooding of SSCs subject to flood protection. The measures for protecting against external flooding are reviewed by and coordinated with the organization responsible for the review of DSRS Sections 2.4.1 through 2.4.14.
4. An assessment of the potential flooding of SSCs subject to flood protection due to the operation of the fire protection system and the postulated pipe failures in accordance with DSRS Section 3.6.2, as well as postulated failures of non-seismic and non-tornado protected piping, tanks, and vessels. DSRS Section 3.6.2 provides guidance for the determination of seismically qualified high energy line breaks or cracks and seismically

qualified moderate energy line cracks. For the purposes of flood analysis, the reviewer need only assume, for each analyzed area, the rupture of the single, worst-case pipe (or non-seismic tank/vessel). If the dynamic effects of the worst-case pipe rupture causes additional rupture of the nearby pipes, the resulting pipe rupture needs to be considered as a part of the worse-case.

Moderate energy piping that is not seismically supported should be considered for full circumferential ruptures, not just cracks.

This assessment should consider ways to mitigate the consequences of potential internal flooding to SSCs subject to flood protection, such as drains and sump pumps. If a postulated break is in a non-seismically supported system, then only seismically-qualified systems should be assumed to be available to mitigate the effects of the analyzed break (since a seismic event may have caused the failure).

The environmental effects of piping failures are assessed in accordance with DSRS Section 3.6.1, and the determination of mechanistic rupture locations and the resulting dynamic effects are evaluated in accordance with DSRS Section 3.6.2.

5. A review of the applicant's risk assessment of external and internal flooding should be performed in consultation with the organization responsible for the review of the PRA to identify potentially significant vulnerabilities to flooding, including an analysis of flooding during shutdown conditions. A failure modes and effects analysis may be performed to determine that the flooding consequences resulting from failures of such liquid-carrying systems close to essential equipment will not preclude required functions of safety systems.
6. A review of the SAR to ascertain if SSCs subject to flood protection are capable of normal function while completely or partially flooded.
7. A review of plant arrangement and layout drawings to determine if equipment or components subject to flood protection are located within individual compartments or cubicles which act as positive barriers against possible means of flooding, and if barriers or other means of physical separation are utilized between redundant safety-related trains. The review also will identify possible flow paths from interconnected nonsafety-related areas to rooms that house SSCs subject to flood protection (e.g., leakage through interconnecting doorways).
8. A review of the design features that will be used to mitigate the effects of internal flooding (e.g., adequate drainage, sump pumps, etc.) if these features are safety-related or risk-significant to ensure adequate time to perform a safe shutdown. Only seismically-qualified systems should be assumed to be available to mitigate the effects of the flooding from non-seismic systems.
9. A review of plant structure design drawings to determine if the flood protection of any , structure subject to flood protection such as below-grade groundwater seepage depends on a permanent dewatering system. If so, the dewatering system should be designed as a safety-related system, and should meet the single failure criterion requirements. In addition, a review of the accidental release of radioactive liquid effluents into the groundwater should be performed in accordance with DSRS Section 2.4.13. Onsite external tank failure should be reviewed for the flood protection of any SSCs subject to flood protection by looking into site grading, sealing of the affected building openings and penetrations, and hydrodynamic loading on building structures.

10. 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 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.

The internal flood protection review included all systems and components whose failure could prevent immediate safe shutdown of the plant and maintenance thereof for the duration beyond 72 hours or result in significant uncontrolled release of radioactivity. In addition, the review included all risk-significant nonsafety-related SSCs whose failure could adversely impact risk-significant functions. Based on the review of the applicant's proposed design criteria, design bases, and safety classifications for safety-related SSCs necessary for a safe plant shutdown during and following the flood condition from either external or internal causes, the staff concludes that the design of the facility for flood protection conforms to the requirements as set forth in 10 CFR Part 50, Appendix A, GDC 2 and GDC 4. This conclusion is based on the applicant having met these requirements with respect to protection of SSCs subject to flood protection from the effects of external and internal flooding by:

1. Identifying all possible sources of internal flooding, including all pipe breaks or cracks postulated in DSRS Sections 3.6.1 and 3.6.2 for seismically qualified high energy and moderate energy lines, full circumferential breaks of non-seismic moderate energy piping, failures of non-seismic internal and external tanks and vessels, backflow through drains, and operation of the fire protection system. The application also considers possible flow paths from non-safety related areas into areas containing SSCs subject to flood protection.
2. Using a method that has been reviewed and found acceptable by the staff to protect SSCs important to safety from flooding by external and internal causes. The design includes the separation of redundant trains of safety-related or risk-significant SSCs, the use of protective barriers and enclosures wherever necessary, the placement of essential SSCs above internal flood levels, and an analysis that shows that any safety-related SSCs subject to flooding will retain their safety function if submerged.
3. Using a safety-related dewatering system that meets single-failure criteria if safety-related SSCs depend on its operation to maintain their safety function.

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 DSRS section.

In addition, to the extent that the review is not discussed in other DSRS 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 2, "Design Bases for Protection Against Natural Phenomena."
1. 10 CFR Part 50, Appendix A, GDC 4, "Environmental and Dynamic Effects Design Bases."
2. RG 1.29, "Seismic Design Classification."