



**U.S. NUCLEAR REGULATORY COMMISSION**  
**STANDARD REVIEW PLAN**

### **3.6.1 PLANT DESIGN FOR PROTECTION AGAINST POSTULATED PIPING FAILURES IN FLUID SYSTEMS OUTSIDE CONTAINMENT**

#### **REVIEW RESPONSIBILITIES**

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

**Secondary -** None

#### **I. AREAS OF REVIEW**

The plant design for protection against piping failures outside containment is reviewed to ensure that environmental effects of such failures would not cause the loss of needed functions of safety-related systems and to ensure that the plant could be safely shut down in the event of such failures. The review includes high energy and moderate energy fluid system piping located outside of containment. If such a system penetrates containment (except for the auxiliary feedwater system) the review starts with the first isolation valve outside of containment. The review boundary for auxiliary feedwater systems extends either to the steam generator or to the feedwater (or steam) line, as appropriate. This section includes a reviews of the plant design to ensure conformance with the requirements of 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 2, and GDC 4.

The specific areas of review are as follows:

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#### **USNRC STANDARD REVIEW PLAN**

This Standard Review Plan, NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC's regulations. The Standard Review Plan is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The standard review plan sections are numbered in accordance with corresponding sections in Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of Regulatory Guide 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by email to [NRR\\_SRP@nrc.gov](mailto:NRR_SRP@nrc.gov).

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1. Reviews of the general layout of high and moderate energy piping systems with respect to the plant arrangement criteria of Section B.1. of Branch Technical Position (BTP) 3-3. Three arrangement situations are covered by the criteria and all three may be encountered in a single plant. They are:
  - A. Arrangements where protection of safety-related plant features is provided by separation of high and moderate energy systems from essential systems and components.
  - B. Arrangements where protection of safety-related plant features is provided by enclosing either the high and moderate energy systems or the safety-related features in protective structures.
  - C. Arrangements where neither separation nor protective enclosures are practical and special protective measures are taken to ensure the operability of safety-related features.
2. Review of portions of high and moderate energy fluid system piping between containment isolation valves that are subject to the recommendations of item B.2.c. of BTP 3-3.
3. Review of analyses and environmental effects of postulated piping failures with respect to the guidelines of Section B.3. of BTP 3-3.
4. Reviews of the assumptions made in the analyses with regard to:
  - A. The availability of offsite power.
  - B. The failure of a single active component in systems used to mitigate the consequences of the piping failure.
  - C. The special provisions applicable to certain dual purpose systems.
  - D. The use of available systems to mitigate the consequences of the piping failure.
5. Review of the effects of postulated failures on the habitability of the control room and access to areas important to safe control of post-accident operations.
6. Review of the effects of piping failures in systems not designed to seismic Category I standards on essential systems and components.
7. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this SRP section in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this SRP section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

8. COL Action Items and Certification Requirements and Restrictions.  
For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

### Review Interfaces

Other SRP sections interface with this section as follows:

1. The acceptability of seismic classification is evaluated in accordance with SRP Sections 3.2.1 and 3.2.2.
2. The acceptability of design of protective structures (such as those used for protection against piping failures) in connection with the review of other Category I structures is evaluated in accordance with SRP Section 3.8.4.
3. The acceptability of the locations and types of piping failures to be considered, the design of piping restraints and other protective measures, and the resultant dynamic effects is evaluated in accordance with SRP Section 3.6.2.
4. The adequacy of internal flood protection system from piping failures is evaluated in accordance with SRP Section 3.4.1.
5. The evaluation of the environmental effects of pipe rupture, (e.g., temperature, humidity, and spray-wetting) with respect to the functional performance of essential electrical equipment and instrumentation is in accordance with SRP Section 3.11.
6. Review of leak-before-break technology to exclude the dynamic effects of postulated pipe ruptures from the design basis of plant SSCs is in accordance with SRP Section 3.6.3.
7. The acceptability of inservice inspection criteria of piping within protective structures or guard pipes, between containment isolation valves is evaluated in accordance with SRP Section 6.6.
8. The acceptability of environmental effects of piping failures inside containment is evaluated in accordance with SRP Sections 6.2.1 and 3.11.

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

## II. ACCEPTANCE CRITERIA

### Requirements

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

1. 10 CFR Part 50, Appendix A, GDC 2, as it relates to protection against natural phenomena, such as seismically-induced failures of non-seismic piping. The application of 10 CFR Part 50, Appendix A, GDC 2 to this section is to incorporate environmental effects of full-circumferential ruptures of non-seismic moderate energy piping in areas where effects are not already bounded by failures of high energy piping. Acceptance is based on conformance to BTP 3-3.
2. GDC 4, as it relates to SSCs important to safety being designed to accommodate the effects of and to be compatible with the environmental conditions associated with postulated pipe rupture. Acceptance is based on conformance to BTP 3-3.
3. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria (ITAAC) that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations;
4. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

### SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

The application of GDC 2 to this section is to incorporate environmental effects of full-circumferential ruptures of non-seismic moderate energy piping in areas where effects are not already bounded by failures of high energy piping. The application of GDC 4 to this section is that the design of SSCs important to safety will accommodate the effects of the environmental conditions associated with postulated pipe ruptures of high and moderate energy piping. Acceptance is based on conformance to BTP 3-3.

1. High and moderate energy fluid systems are separated from essential systems and components, as described in Appendix B to BTP 3-3.
2. High and moderate energy fluid systems, or portions thereof, are enclosed as described in item B.1.b of BTP 3-3.
3. For cases where neither physical separation nor protective enclosures are considered practical by the applicant, the reviewer will verify the following:
  - A. The reasons for which the applicant judged both physical separation and system enclosure to be impractical as means of protection are consistent with item B.1.c. of BTP 3-3.
  - B. Redundant design features or additional protections (assuming a single active failure in any required system) have been provided such that failure modes and effects analyses for all failure situations ensure the performance of safety features. These analyses are done under the criteria and assumptions of item B.3. of BTP 3-3.
4. Design Features are in accordance with item B.2 of BTP 3-3.
5. The effects of postulated failures on essential equipment and the ability of the plant to be safely shut down are analyzed in accordance with item B.3. of BTP 3-3.

#### 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. Compliance with GDC 2 requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety function.

Meeting the requirements of 10 CFR 50, Appendix A, GDC 2 is necessary to ensure that environmental effects due to failures of non-seismic piping do not affect the ability of the plant to shut down safely and remain in safe shutdown condition. The application of GDC 2 to this SRP Section is to ensure that consideration is given to full-circumferential ruptures of non-seismic moderate energy piping. Such ruptures are not postulated for dynamic considerations under SRP Section 3.6.2 since that section only applies for normal plant conditions, not seismic events; however, environmental effects from these ruptures should be considered. In many cases, the limiting bound on environmental effects will be from failures of high-energy piping in the same area. However, the applicant should consider the effects on safety-related SSCs in areas where moderate energy failures may be the source of the most extreme postulated environmental effects.

2. Compliance with 10 CFR Part 50, Appendix A, GDC 4 requires that SSCs important to safety shall be designed to accommodate the effects of, and be compatible with, environmental conditions associated with normal operations, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These SSCs should be appropriately protected against dynamic effects (including those of missiles, pipe whipping, and discharge fluids) that may result from equipment failures and from events outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for piping.

GDC 4 requirements are applicable to this SRP section because the reviewer verifies that a suitable and controlled operating environment will be provided for SSCs during normal operations, during anticipated operational occurrences, and during and after postulated accidents, including loss-of-coolant accidents. These requirements are imposed to ensure (a) that piping failures in fluid systems outside the containment will not cause the loss of needed function in safety-related systems and (b) that the plant could be safely shut down in the event of such a failure.

Meeting the requirements of 10 CFR Part 50, Appendix A, GDC 4 provides assurance that safety-related SSCs will be able to maintain their safety-related functions in the environmental conditions resulting from a postulated piping failure.

### III. REVIEW PROCEDURES

The reviewer will select material from the procedures described below, as may be appropriate for a particular case.

These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

All the systems of concern in this section have been reviewed under other SRP sections with respect to design functions for normal operation and for the prevention or mitigation of accidents. The review under this SRP section does not deal with individual system design criteria necessary to ensure that each system performs as intended, but rather considers the protection necessary to ensure the operation of such systems in the event of nearby piping failures.

1. A review of the information presented in the Safety Analysis Report (SAR) identifying all high and moderate energy fluid systems, and verification of individual system temperatures and pressures to ensure that they have been correctly identified. The reviewer evaluates for adequacy the system descriptions of the high and moderate energy piping runs and by reviewing the appropriate system arrangement and piping drawings, examines the plant arrangement measures that were taken to ensure protection from the effects of postulated pipe breaks of high energy systems and non-seismic moderate energy systems, or of leakage cracks for seismically-designed

moderate energy systems. The reviewer will determine from the SAR that the following configurations, either by itself or in combination, have been used by the applicant to achieve this protection:

- A. High and moderate energy fluid systems are separated from essential systems and components, as described in Appendix B to BTP 3-3. The reviewer inspects plant arrangement drawings and other information to verify conformance to Appendix B to BTP 3-3.
  - B. High and moderate energy fluid systems, or portions thereof, are enclosed within structures or compartments designed to protect nearby essential systems or components, or the essential systems and components are enclosed in protective structures. The reviewer traces the routing of the systems identified in the SAR as high or moderate energy systems on appropriate plant arrangement drawings, locates the postulated break locations specified in the applicant's analyses, and determines all locations where the effects from the breaks or leaks interface with safety-related equipment. The reviewer then determines that at these locations enclosures have been provided that protect the safety-related equipment. Any questions related to the location of the break are conveyed to the organization responsible for the review of SRP Section 3.6.2 for a determination of the proper locations.
  - C. For cases where neither physical separation nor protective enclosures are considered practical by the applicant, the reviewer will analyze the SAR information to verify the following:
    - i. The reasons for which the applicant judged both physical separation and system enclosure to be impractical as means of protection are consistent with item B.1.c. of BTP 3-3.
    - ii. Redundant design features or additional protections (assuming a single active failure in any required system) have been provided such that failure modes and effects analyses for all failure situations ensure the performance of safety features. These analyses are done under the criteria and assumptions of item B.3. of BTP 3-3. Special measures taken to provide additional protection are reviewed on a case by case basis, with assistance from other staff as needed.
2. Review the information presented in the SAR that identifies the principal design features. The reviewer performs the evaluation by comparing the design basis information given in the SAR with that described in item B.2. of BTP 3-3. By this comparison of individual design features, the reviewer verifies that the following necessary measures have been provided by the applicant's design.
- A. Design features provided for protective structures or compartments and other protective measures are reviewed as described in item B.2.b. of BTP 3-3. The reviewer compares the design features and bases given in the SAR with the stated item in BTP 3-3. The comparative review may include the use of plant arrangement and layout drawings as necessary to clarify the design intentions

and implementation. In the majority of case reviews, SAR statements and drawings indicating that the design meets the intent of the acceptance criteria are accepted. However, there may be cases where engineering judgment and independent staff analyses are needed to verify the capability of structures and components to withstand the effects of a pipe rupture.

- B. SAR information, as supplemented by engineering sketches or drawings where necessary, is reviewed to determine that fluid system piping between containment isolation valves conforms to item B.2.c. of BTP 3-3. This includes piping penetrations between single and dual barrier containments that may have enclosing protective structures. The review is mainly performed on a comparative basis in this SRP Section. These piping details are reviewed to verify the design limits, break locations, and dynamic effects under SRP Section 3.6.2 and BTP 3-4
3. The results of the applicant's evaluation of the environmental consequences of postulated piping failures of high and moderate energy fluid piping systems are reviewed. The type and location of each postulated piping failure (i.e., longitudinal or circumferential) in either a high or moderate energy system will be reviewed by the organization responsible for the mechanical engineering reviews on the basis of BTP 3-4; however, full-circumferential breaks in non-seismic moderate energy piping should be considered in addition to the breaks postulated in BTP 3-4. The review will be based upon the information provided by applicants in the SAR concerning the effects of postulated failures on essential equipment and the ability of the plant to be safely shut down, as described in item B.3. of BTP 3-3.

The reviewer verifies that the applicant's evaluation has properly considered the following points, and in certain cases, as necessary, performs an independent evaluation, especially with regard to single failure analyses.

- A. The reviewer verifies the applicant's plant arrangements and design features using layout drawings to ensure that all potentially affected essential systems and components have been considered with respect to the effects of an assumed pipe break.
- B. The reviewer evaluates the effects of postulated piping failures as determined from the information given in the SAR. The reviewer will confirm the results of the applicant's evaluations by performing a comparative, but abbreviated as appropriate, failure modes and effects analysis that includes the considerations given in item B.3.b. of BTP 3-3 for the following effects:
  - i. The availability of offsite power.
  - ii. The effects of a single active component failure in systems necessary to mitigate consequences of the postulated piping break.
  - iii. Permissible exclusions to (ii.) above based upon the provision given in item B.3.b.(3) of BTP 3-3 for certain dual purpose moderate energy systems.



- iv. The considerations involved in the selection of available systems to mitigate the consequences of the piping failure.
  - C. The reviewer will verify from a review of arrangement drawings that control room habitability or access to necessary surrounding areas is not jeopardized as a consequence of the postulated piping failure.
  - D. The reviewer evaluates the applicant's analysis of the postulated failure of non-seismic Category I piping systems by performing a failure modes and effects analysis using SAR information and engineering sketches as necessary.
4. Systems defined in Appendix A to BTP 3-3 as "essential systems" are those that are needed to shut down the reactor and mitigate the consequences of the pipe break for a given postulated piping break without offsite power. However, depending upon the type and location of the postulated pipe break, certain safety equipment may not be classified as "essential" for that particular event (e.g., emergency power system or high and low pressure core spray systems). On the other hand, some safety equipment will be "essential" for almost all cases (e.g., service water to ultimate heat sink). Table 3.6.1-1 is a list of those essential systems generally in the latter category.
5. 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 ESP or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

For review of both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

TABLE 3.6.1-1

SYSTEMS USUALLY REQUIRED FOR SAFE SHUTDOWN

<u>PWR</u>	<u>BWR</u>
Service Water System	Service Water System
Auxiliary Feedwater System	Reactor Coolant Injection System
Volume Control System	Automatic Depressurization System
Decay Heat Removal System	Residual Heat Removal System
Component Cooling Water System	Component Cooling Water System (if provided)

Table 3.6.1-2 is a listing of systems typically classified as either high or moderate energy systems that are located outside the primary containment in pressurized water reactor (PWR) and boiling water reactor (BWR) plants.

TABLE 3.6.1-2

TYPICAL HIGH ENERGY SYSTEMS OUTSIDE CONTAINMENT

<u>PWR</u>	<u>BWR</u>
Main Steam Line System	Main Steam Line System
Main Feedwater Line System	Main Feedwater Line System
Auxiliary Feedwater System	High Pressure Core Spray System
Volume Control System	Process Sampling System
Process Sampling System	Condensate System
Condensate System	Reactor Cleanup System
Steam Generator Blowdown Line	Standby Liquid Control System

TYPICAL MODERATE ENERGY SYSTEMS OUTSIDE CONTAINMENT

<u>PWR</u>	<u>BWR</u>
Service Water System	Service Water System
Decay Heat Removal System (outside of reactor coolant pressure boundary)	Residual Heat Removal System (outside of reactor coolant pressure boundary)
Circulating Water System	Circulating Water System
Fire Protection System	Fire Protection System
Component Cooling Water System	Component Cooling Water System

#### IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

The review of the plant design for protection against postulated piping failures outside containment included all high and moderate energy piping systems located outside containment. The review of these high and moderate energy systems for the \_\_\_\_\_ plant included layout drawings, piping and instrumentation diagrams, and descriptive information.

The staff concludes that the facility design for protection against postulated piping failures outside containment is acceptable and therefore meets the requirements of 10 CFR Part 50, Appendix A, GDC 2, GDC 4, 10 CFR 52.47(b)(1), and 10 CFR 52.80(a) with respect to accommodating the environmental effects of postulated pipe ruptures. The applicant has met the requirement of GDC 2 by considering the environmental effects from the rupture of non-seismic piping, and the applicant has met the requirement of GDC 4 with respect to postulated pipe ruptures by conforming to BTP 3-3.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this SRP section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

#### V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision. Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced Branch Technical Positions.

#### VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Dynamic Effects Design Bases."
2. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

3. Branch Technical Position 3-3, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment."
4. Branch Technical Position 3-4, "Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment."
5. 10 CFR 52.47, "Contents of applications."
6. 10 CFR 52.80, "Issuance of combined licenses."

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**PAPERWORK REDUCTION ACT STATEMENT**

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50 and 10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.

**PUBLIC PROTECTION NOTIFICATION**

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