Reliability Assurance Program for New Reactors and Lessons Learned and Insights Gained

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Abstract: The U.S. Nuclear Regulatory Commission reviews the reliability assurance program (RAP) for new reactor applications using NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 17.4, "Reliability Assurance Program." The RAP applies to those systems, structures, and components (SSCs) that are identified as being risk-significant (or significant contributors to plant safety). These SSCs are identified through probabilistic and deterministic analyses, including information obtained from the probabilistic risk assessment (PRA) and severe accident evaluations. The purposes of the RAP are to provide reasonable assurance that:

- a reactor is designed, constructed, and operated consistent with the risk insights and key assumptions from probabilistic, deterministic, and other methods of analysis
- the SSCs within the scope of RAP do not degrade to an unacceptable level of reliability, availability, or condition during plant operations
- the frequency of transients that challenge these SSCs is minimized
- these SSCs function reliably when challenged

The goal of this paper is to describe the RAP process, taking into consideration the lessons learned and insights gained from RAP reviews of new reactor applications. It also identifies the most recent guidance on RAP, which incorporates these lessons and insights.

Keywords: Reliability Assurance Program, Probabilistic Risk Assessment, PRA, Maintenance Rule.

1. INTRODUCTION

The reliability assurance program (RAP) for new reactors ensures that the design reliability of the systems, structures, and components (SSCs) within the scope of RAP is maintained over the life of a plant. Each design-specific rulemaking incorporates a requirement to provide a RAP in accordance with U.S. Nuclear Regulatory Commission (USNRC) policy documented in the staff requirements memorandum [1] on SECY-95-132, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems (RTNSS) in Passive Plant Designs" [2], Item E, "Reliability Assurance Program." This becomes part of an application for a combined license that references a certified design.

The RAP for new reactors is established using the guidance contained in: (1) Item E of SECY-95-132, and (2) Section 17.4, "Reliability Assurance Program," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP) [3]. The USNRC reviews the RAP for new reactor applications in accordance with Section 17.4 of the SRP.

The purpose of this paper is to describe the RAP process taking into consideration the lessons learned and insights gained from RAP reviews of new reactor applications. It also identifies the most recent guidance on RAP, which incorporates these lessons and insights.

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2. DESCRIPTION OF THE RAP PROCESS

This section describes the details of the RAP process, taking into consideration the lessons learned and insights gained from RAP reviews of new reactor applications.

2.1. Scope, Purpose, Objectives, and Phases of the RAP

The RAP for a new reactor is implemented during its design, construction, and operational phases. The RAP applies to those SSCs, both safety-related and non-safety-related, that are identified as being risk-significant (or significant contributors to plant safety). These SSCs are identified by using a combination of probabilistic, deterministic, and other methods of analysis, including information obtained from sources such as the probabilistic risk assessment (PRA), severe accident evaluations, industry operating experience, and expert panels. The SSCs within the scope of the RAP are referred to hereafter as "RAP SSCs." The purposes of the RAP are to provide reasonable assurance of the following:

- a reactor is designed, constructed, and operated consistent with the risk insights and key assumptions (e.g., SSC design, reliability, and availability) from probabilistic, deterministic, and other methods of analysis
- the RAP SSCs do not degrade to an unacceptable level of reliability, availability, or condition during plant operations
- the frequency of transients that challenge these SSCs is minimized
- these SSCs function reliably when challenged

The purposes of the RAP can be achieved by implementing the program in two stages. The first stage applies to reliability assurance activities that occur before initial fuel load and is referred to as the design reliability assurance program (D-RAP). The second stage applies to reliability assurance activities conducted during the operations phase of the plant's life cycle.

The objective of the D-RAP is to ensure that the reactor is designed and constructed consistent with risk insights and key assumptions (e.g., SSC design, reliability, and availability) from probabilistic, deterministic, and other methods of analysis. This objective can be achieved through the following:

(a) Apply the essential elements of D-RAP (i.e., organization, design control, corrective actions, procedures and instructions, records, and audit plans) during design and construction activities. These essential elements ensure that the risk insights and key assumptions are consistent with the reactor design and construction, and that the list of RAP SSCs is appropriately developed, maintained, and communicated to the appropriate organizations (see Section 2.2 of this paper for a detailed discussion of the essential elements of D-RAP).

(b) Implement the appropriate quality assurance (QA) programs related to design and construction activities (e.g., design, procurement, fabrication, construction, inspection, and testing activities) to provide control over activities affecting the quality of the RAP SSCs. QA controls for safety-related SSCs are established through Title 10 of the Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants" [4]. The provisions in Section 17.5, Part V, "Non-safety-Related SSC Quality Controls," of the SRP [3] address QA controls for non-safety-related RAP SSCs.

D-RAP can be implemented through the following phases:

(a) During the design certification (DC) phase, the DC applicant develops and implements those portions of the D-RAP that apply to the DC. This effort includes (1) describing the details of the D-RAP (e.g., scope, purpose, objectives, framework, and phases of the D-RAP) that will be implemented during the DC and combined license (COL) phases, (2) applying the essential elements of D-RAP during DC design activities, (3) determining the RAP SSCs using a combination of probabilistic, deterministic, and other methods of analysis, and (4) implementing the appropriate QA controls related to DC design activities for the non-safety-related RAP SSCs in accordance with Part V of SRP Section 17.5. In addition, the DC applicant proposes non-system-based Tier 1 inspections, tests, analyses, and acceptance criteria (ITAAC) [5] for the COL D-RAP. The USNRC verifies the adequacy of the DC applicant's D-RAP, including its implementation during the DC application phase, through the agency's safety evaluation review process, which may include audits.

(b) During the COL application phase, the COL applicant develops and implements those portions of the D-RAP that apply to the COL. This effort includes (1) applying the essential elements of D-RAP during COL design activities, (2) determining the SSCs in the scope of the COL's plant-specific D-RAP (i.e., the RAP SSCs identified in the DC, updated using plant-specific information) by introducing plant-specific information into the probabilistic, deterministic, and other methods of analysis, and (3) implementing the appropriate QA controls related to COL design activities for the non-safety-related RAP SSCs in accordance with Part V of SRP Section 17.5. The USNRC verifies the adequacy of the COL applicant's D-RAP, including its implementation during the COL application phase, through the agency's safety evaluation review process, which may include audits.

In addition, the COL applicant proposes a process for integrating RAP into operational programs to meet the objectives of the RAP during the operations phase. The objectives of the RAP during the operations phase can be accomplished within the following operational programs: (1) the maintenance rule program established through 10 CFR Section 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants" [6]; (2) the QA program for safety-related SSCs established through Appendix B to 10 CFR Part 50; (3) QA controls for non-safety-related RAP SSCs established in accordance with Part V of SRP Section 17.5; and (4) the in-service inspection and testing, surveillance testing, and maintenance programs.

(c) Prior to initial fuel load, the COL holder is responsible for implementing the D-RAP, which includes (1) applying the essential elements of D-RAP during COL design and construction activities (which includes updating the list of RAP SSCs as changes are made to plant-specific design and PRA), (2) implementing the appropriate QA controls related to COL design and construction activities for the non-safety-related RAP SSCs in accordance with Part V of SRP Section 17.5, and (3) completing the ITAAC for the D-RAP. The USNRC verifies implementation of the plant-specific D-RAP during this phase using inspections. Satisfactory completion of the D-RAP ITAAC is verified by using USNRC Inspection Manual Chapter 2503, "Construction Inspection Program: Inspections of Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)" [7].

The objective of the RAP during the operations phase of the plant's life cycle is to ensure that the reliability and availability of RAP SSCs are maintained commensurate with their risk significance. The COL holder identifies dominant failure modes and integrates RAP into operational programs to meet the objectives of the RAP during the operations phase. Performance and condition monitoring is implemented to provide reasonable assurance that these RAP SSCs do not degrade to an unacceptable level of reliability, availability, or condition. The USNRC verifies implementation of reliability assurance activities associated with the operations phase using inspections for the duration of the license.

2.2. Essential Elements of D-RAP

During USNRC reviews of new reactor applications, the reviews of the essential elements of D-RAP were often difficult due to the wording of the acceptance criteria in SRP Section 17.4. In addition, COL applicants, in general, did not describe the essential elements related to their plant-specific D-RAP. The USNRC addressed these issues during the RAP reviews using one or more requests for additional information (RAIs). Review of the responses to the RAIs provided the staff with new insights. Based on the lessons learned and insights gained from these reviews, the staff issued DC/COL-ISG-018, "Interim Staff Guidance on NUREG-0800 Standard Review Plan Section 17.4, Reliability Assurance Program" (ISG-18) [8], which describes the essential elements of D-RAP as follows.

Each DC and COL applicant should establish and apply the essential elements of D-RAP during design and construction activities. These essential elements ensure that the risk insights and key assumptions are consistent with the reactor design and construction, and that the list of RAP SSCs is appropriately developed, maintained, and communicated to the appropriate organizations. The essential elements of D-RAP include:

(a) establishing appropriate interfaces within the DC and COL organizations to ensure that the reactor will be designed and constructed consistent with the risk insights and key assumptions

Interfaces between those organizations that establish the scope of the D-RAP, as well as those that develop, coordinate, or implement D-RAP activities should ensure that the reactor will be designed and constructed in a manner that is consistent with the risk insights and key assumptions. This includes establishing appropriate interfaces in the design change control process for the purpose of updating and providing relevant D-RAP inputs (e.g., list of RAP SSCs, PRA models, key assumptions, and risk insights) to account for design changes.

(b) subjecting D-RAP activities to the appropriate design controls

The design change control process should provide a mechanism for notifying the appropriate organizations of changes (e.g., design changes, program changes, or PRA changes) that could affect the RAP SSCs or relevant D-RAP inputs. Quality controls should be established to ensure D-RAP activities meet the predetermined requirements, recommendations, or specifications. This includes quality controls for: identifying the RAP SSCs, the analyses used to identify these SSCs (i.e., probabilistic, deterministic, and other methods of analysis), and ensuring that the relevant D-RAP inputs are maintained or updated, as necessary, and reflect the designed and constructed plant. A configuration control process should maintain the list of RAP SSCs.

(c) establishing a corrective action process for D-RAP activities

This process ensures that the D-RAP activities determined to be in error, deficient, or nonconforming are promptly identified, reported, and corrected. For example, information used to identify RAP SSCs may be determined to be incorrect, or there may be a failure to communicate a key assumption to the design organization.

(d) establishing detailed procedures or instructions used for developing, coordinating, and implementing D-RAP activities

(e) preparing and maintaining records associated with D-RAP activities to demonstrate that all requirements for D-RAP activities have been met

(f) conducting audits of D-RAP activities

2.3. Methodology for Identifying RAP SSCs

During USNRC reviews of new reactor applications, the reviews of the methodology for evaluating and identifying the list of RAP SSCs were often difficult due to the wording of the acceptance criteria in SRP Section 17.4. Also, these lists were, in general, incomplete because the applicants did not consider the full spectrum of risk evaluations considered in Section 19.0, "Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors," of the SRP [3] and limited the scope of the RAP to only risk-significant SSCs modeled in the PRA. The USNRC addressed these issues during the RAP reviews using the RAI process. Based on the lessons learned and insights gained from these reviews, the staff issued ISG-018 [8], which describes the methodology for evaluating and identifying the list of RAP SSCs as follows.

The SSCs within the scope of the RAP should be identified by using a combination of probabilistic, deterministic, and other methods of analysis that includes, but not limited to, the use of information obtained from the following sources:

- risk evaluations that cover the full spectrum of potential events and the range of plant operating modes considered in SRP Section 19.0, which includes the use of non-PRA type evaluations (e.g., fire-induced vulnerability evaluation or seismic margins analysis) when PRAs have not been performed

  For example, identification of RAP SSCs based on importance measures, risk insights, and key assumptions from severe accident evaluations and full power or low-power/shutdown PRAs for internal events, fire, seismic, flooding, and other external events.

- industry operating experience

- expert panel(s)

An expert panel plays an important role in reviewing the information associated with risk significance determinations and could compensate for the limitations of the PRA. To evaluate and review information associated with determinations of risk-significance, the expert panel should comprise plant knowledgeable members whose collective expertise includes, at a minimum, PRA, safety analysis, plant operations, maintenance, design engineering, and system engineering. Expert panel members should have a level of knowledge sufficient to evaluate and approve risk significance determinations using both probabilistic and deterministic information.

The scope of RAP is not limited to risk-significant SSCs modeled in the PRA. Therefore, SSCs that are not modeled in the PRA should also be evaluated for inclusion in RAP (e.g., by using deterministic or other methods of analysis). The scope of RAP should include safety-related and non-safety-related SSCs identified as risk-significant (or significant contributors to plant safety). For passive system designs, RAP should also include all SSCs subject to RTNSS.

2.4. ITAAC for D-RAP

During USNRC reviews of new reactor applications, both USNRC staff and DC applicants commonly interpreted the acceptance criteria in SRP Section 17.4 for D-RAP ITAAC as a numerical analysis that would require the estimated reliability of each as-built RAP SSC to be at least equal to the reliability assumed in the PRA. However, D-RAP should not be based solely on numerical values. For one reason, the estimated reliability of each as-built RAP SSC and the reliability assumed in the PRA may be highly uncertain. For another, the basis for the estimated reliability of each as-built RAP SSC may be the same as, or very similar to, the basis for the reliability assumed in the PRA. Therefore, only calculating and comparing numerical values may not be useful. Finally, additional aspects of D-RAP should be considered in order to address other risk insights and key assumptions. The staff concluded that implementation of D-RAP should be interpreted as having a process that would control reliability

and availability of RAP SSCs. This process includes implementing the appropriate QA programs to provide control over activities affecting the quality of the RAP SSCs. The USNRC addressed this issue during the RAP reviews using the RAI process. Based on the lessons learned and insights gained from these reviews, the staff issued ISG-018 [8], which describes the ITAAC for D-RAP as follows:

> "The DC applicant should specify an ITAAC for the D-RAP to ensure that appropriate controls are applied to the RAP SSCs during the COL design phase of the reactor (e.g., ensuring that the design bases and other requirements have been correctly translated into the detailed design documents used for procurement and construction of the RAP SSCs). The design commitment for the D-RAP ITAAC should ensure that the design of RAP SSCs is consistent with the risk insights and key assumptions (e.g., SSC design, reliability, and availability). An analysis will confirm that the design of all RAP SSCs has been completed in accordance with applicable D-RAP activities. The acceptance criteria for the D-RAP ITAAC is all RAP SSCs have been designed in accordance with the applicable reliability assurance activities for the D-RAP."

It should be noted that the implementation of the D-RAP during the construction phase of the reactor is verified by the USNRC using inspections. In addition, other ITAAC will confirm that the as-built plant conforms to the detailed design.

2.5. Integration of RAP into Operational Programs

During USNRC reviews of new reactor applications, the reviews of the process for integrating RAP into operational programs were often difficult due to the wording of the acceptance criteria in SRP Section 17.4. In addition, the process proposed by some COL applicants did not meet the objectives of the RAP during the operations phase. The USNRC addressed these issues during the RAP reviews using the RAI process. Based on the lessons learned and insights gained from these reviews, the staff issued ISG-018 [8], which describes the integration of RAP into operational programs as follows.

The objective of the RAP during the operations phase of the plant's life cycle is to ensure that the reliability and availability of RAP SSCs are maintained commensurate with their risk significance. The process for integrating the RAP into operational programs should address the following activities:

(a) Establish reliability, availability, or condition performance goals for the RAP SSCs. Implementation of the maintenance rule following the guidance contained in Regulatory Guide (RG) 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants" [9], is one acceptable method for establishing these performance goals, provided that these SSCs are categorized as having high safety significance (HSS).

(b) Establish performance and condition monitoring requirements to provide reasonable assurance that RAP SSCs do not degrade to an unacceptable level of reliability, availability, or condition during plant operations. (The reliability performance monitoring does not need to statistically verify the numerical values used in the PRA. However, it provides a feedback mechanism for periodically evaluating equipment reliability and risk significance based on actual equipment, train, or system performance and other operational history.)

(c) For the non-safety-related RAP SSCs, establish QA controls for COL operational activities (which include establishing appropriate corrective actions for potential design and operational errors that degrade these SSCs) in accordance with the provisions in Part V of SRP Section 17.5.

(d) Use dominant failure modes of RAP SSCs to identify specific operational reliability assurance activities or strategies (e.g., in-service inspection and testing, surveillance testing, monitoring, and maintenance) to maintain equipment performance consistent with the risk insights and key assumptions for the RAP SSCs.

One acceptable method for meeting the objectives of the RAP during the operations phase is by implementation of the following operational programs: (1) maintenance rule program consistent with RG 1.160, with all RAP SSCs being categorized as having HSS, (2) QA program for safety-related SSCs established through Appendix B to 10 CFR Part 50, (3) QA controls for non-safety-related RAP SSCs established in accordance with Part V of SRP Section 17.5, and (4) in-service inspection and testing, surveillance testing, and maintenance programs for the RAP SSCs to maintain equipment performance consistent with the risk insights and key assumptions.

3. CONCLUSION

The RAP for new reactors is established using the guidance contained in Item E of SECY-95-132 and SRP Section 17.4. The USNRC staff reviews the RAP for new reactor applications in accordance with Section 17.4 of the SRP. In this paper, the RAP process is described taking into consideration the lessons learned and insights gained from RAP reviews of new reactor applications.

These lessons learned and insights gained are incorporated into USNRC interim staff guidance ISG-018 [8] to assure the quality and uniformity of USNRC safety reviews of the RAP, as well as to improve communication between the USNRC, the nuclear power industry, and interested members of the public.

References

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