TECHNICAL SPECIFICATION SURVEILLANCE REQUIREMENT FREQUENCY IMPROVEMENTS IN NUCLEAR POWER PLANTS VIA RISK-INFORMED INITIATIVE-5B APPROACH

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This paper will provide the technical basis and methods necessary to justify changes to surveillance frequencies consistent with the risk-informed approach defined in Regulatory Guide (RG) 1.174 Revision 2 (Reference 1) and following the methodology defined in NEI 04-10, Revision 1 (Reference 2). The impact on plant risk and the impact on deterministic considerations, such as defense-in-depth, safety margins, and component/system performance, will not be addressed.

Objectives of this paper are to: (1) provide an introduction to Technical Specifications (TSs) and Surveillance Requirements (SRs), (2) provide a high-level overview of TS SR frequency improvement program (Risk-Informed 5b) and its benefits and (3) discuss different approaches following the Risk-Informed 5b methodology to justify surveillance test frequency changes.

I. Introduction

The intent of this paper is to discuss different methods on a high level and their technical bases to justify changes to Technical Specification surveillance frequencies consistent with the risk-informed approach and methodology defined in Regulatory Guide (RG) 1.174 (Reference 1) and NEI 04-10, Revision 1 (Reference 2). The industry's Risk-Informed Technical Specifications Task Force (RITSTF) Initiative-5b can be used to relocate the TS surveillance frequencies to a licensee controlled program, i.e., Surveillance Frequency Control Program (SFCP). After relocation, changes can be made to the surveillance frequencies without Nuclear Regulatory commission (NRC) review and approval following the guidance in NEI 04-10, Revision 1. The NRC approved NEI 04-10, Revision 1, "Risk-Informed Method for Control of Surveillance Frequencies," is an industry document that provides the guidance and methodology for implementing this initiative.

By applying the methodology in NEI 04-10, a plant can successfully implement extended surveillance intervals for a large number of Technical Specification Surveillance Requirements related to many plant systems/components. Acceptable risk assessment methodologies that have already been performed will be discussed. These include qualitative approaches, quantitative assessments and bounding analyses with acceptance criteria specified in RG 1.174. Assessment of regulatory requirements, guidance, and standards, together with deterministic considerations, such as defense-in-depth, safety margins, and performance monitoring, will not be discussed.

Benefits of extending the TS surveillance frequency are directly related to the specific surveillance being addressed. For some surveillance frequency extensions there will be a reduction in engineering and technician time required to plan, perform, track, and report on the tests and results. Extension of other surveillances that are required to be completed during a refueling outage, such as the Engineered Safety Features (ESF)/Loss of Offsite Power (LOOP) surveillance and possibly transmitter calibrations, can lead to a reduction in outage time. Other benefits may include (but not limited to) reduction in worker exposures and plant risk.

I.A. Technical Specifications

Technical Specifications are issued by the NRC and are specific to each plant. They ensure the safe nuclear power plant operation and are maintained within the plant's safety analyses bounding conditions and assumptions. TS are legally binding documents plants follow in operation.

TS include sections addressing:

- Safety Limits (SLs)
- Limiting Conditions for Operation (LCOs)
- Surveillance Requirements (SRs)
- Design Features
- Administrative Controls

This paper focusses only on the SRs.

I.B. TS Surveillance Requirements

TS surveillance requirements are requirements relating to test, calibration, and inspection to assure that the quality and reliability of structures, systems, and components (SSCs) are maintained. Surveillance test frequencies can vary from every few hours to as long as 10 years.

Examples of SRs are as follows:

SR	SURVEILLANCE	FREQUENCY
SR 3.7.6.1	Verify the CST level is ≥ [110,000 gal]	12 hours
SR 3.3.1.16	Verify RTS response time is within limits	18 months on STAGGERED BASIS
SR 3.6.6A.8	Verify each spray nozzle is unobstructed	10 years

I.C. Overview of TS SR Frequency Improvements Program

Risk-Informed TS Task Force (RITSTF) Initiative-5b uses probabilistic risk assessment (PRA) risk information along with deterministic requirements to modify TS surveillance frequencies, also known as surveillance test interval (STI) extensions.

Three guidance documents are followed in this TS frequency improvement program:

1. RG 1.174, Revision 2, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" (Reference 1)
2. NEI 04-10, Revision 1, "Risk-Informed Method for Control of Surveillance Frequencies" (Reference 2)
3. RG 1.177, Revision 1, "An Approach for Plant-Specific, Risk-Informed Decisionmaking: Technical Specifications" (Reference 3)

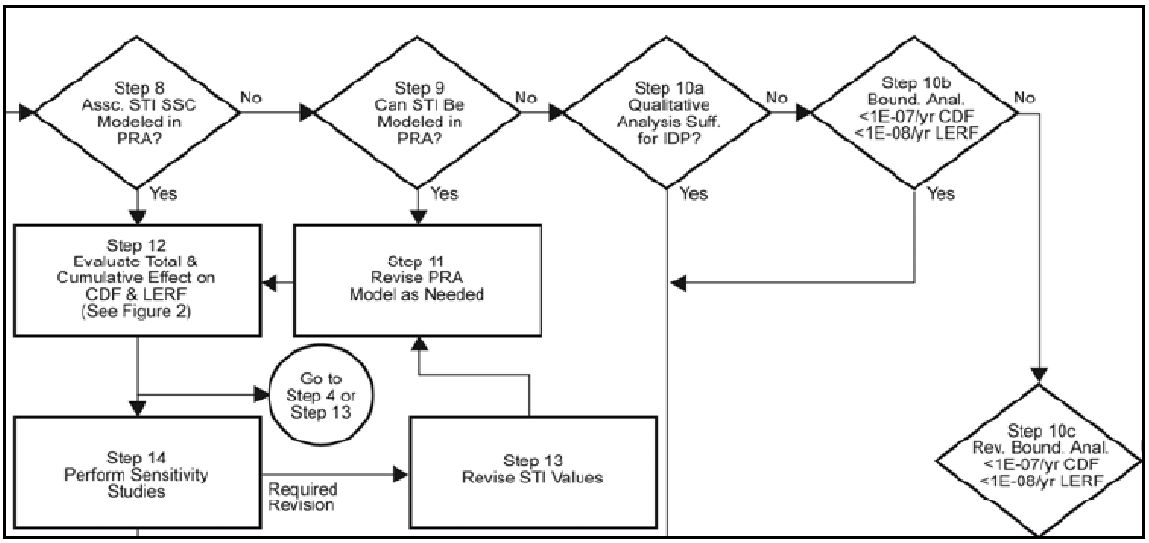
The application of the Risk-Informed TS Initiative-5b is initiated by utilities and the industry on a voluntary basis.

Many benefits can be realized by the application of the Risk-Informed TS Initiative-5b program. These include the reduction of component testing that translates into cost reduction, reduction in component unavailability by reducing the component time out of service required for testing, reduction in plant outage time for SRs that need to be completed during refueling outages, and reduction in worker radiation exposures when the testing is performed in radiation areas. These benefits are directly related to the STI being addressed.

NEI 04-10 provides the guidance for implementation of a generic technical specification improvement that establishes licensee control of surveillance test frequencies for most of the TS frequencies. Existing specific surveillance frequencies that are removed from TS are placed under licensee control by application of this methodology. The surveillance test requirements (i.e., test methods) are not changed but remain in the TS. The NEI 04-10 methodology uses a risk-informed performance approach that is consistent with what is outlined in RG 1.174 and uses PRA methods to determine the risk impact resulting from the revised test intervals. The RG provides quantitative risk acceptance guidelines for changes to core damage frequency (CDF) and large early release frequency (LERF). In conjunction with the NEI 04-10 guidance, a corresponding Technical Specification Task Force (TSTF) 425, Revision 1, relocates the majority of the TS SR frequencies to the utility's licensee-controlled program. The administrative controls section of the TS specifies the requirements for a surveillance frequency control program (SFCP) that the licensee will use to control surveillance frequencies and make future changes to the SR frequencies. Additionally, RG 1.177, Revision 1 (Reference 3), provides more specific guidelines to facilitate application by the licensee for changing surveillance frequencies and completion times (CTs).

II. Risk-Evaluation Portion of the NEI 04-10 Process

The main focus of this paper is the risk-evaluation portion of the NEI 04-10 process. This encompasses Steps 8 through 14 as outlined in Reference 2 once the STI has been identified.



Step 8 of NEI 04-10 asks the question is the "Associated STI SSC Modeled in PRA?" This is to determine if the surveillance or the associated structures, systems, and components (SSCs) are modeled in the PRA. Internal events are of concern at this point. To assess if the STI change can be adequately modeled by the PRA the following actions shall be taken:

- Develop a list of components affected by the STI change. Establish the PRA modeled components sufficiently represent the SSCs affected by the STI change.
- Determine if the failure contribution of the SSCs is based on recognized data sources or plant-specific data as per discussion in Reference 1. Most often, the total failure probability is assumed to be time-related.
- For the SSCs impacted by the STI change, determine that the model includes common cause failures (CCFs).

If the PRA model meets these conditions, proceed to Step 12 to determine CDF and LERF for the revised STI values. Otherwise go to Step 9.

Step 9 "Can STI Be Modeled in PRA?" is entered if Step 8 determined that the SSCs affected by the STI change are not sufficiently modelled. The analyst has to determine if the STI can be adequately represented in the PRA model. This determination applies to all PRAs including external events and shutdown (if available) with the initial focus on the internal events PRA. If the PRA does not sufficiently represent the SSCs being considered for the STI change with some revisions, proceed to Step 10. If the PRA can be revised to sufficiently represent the SSCs being considered for STI change, go to Step 11.

Step 10 "Perform Qualitative or Bounding Risk Analysis" is entered from Step 9 if the PRA does not sufficiently represent the SSCs being considered for the STI change. Performance of a qualitative or bounding analysis will provide some indication of the impact of the STI change on CDF and LERF. Qualitative analysis does not use numerical values. Bounding analysis would use limited numerical values in the assessment. Additionally, external, flood, fire, seismic, and shutdown events should be addressed either qualitatively or quantitatively to assess the plant-risk per each type of event based upon the STI change considered.

Step 10a "Qualitative Analysis Sufficient for Integrated Decision-making Panel (IDP)?" is performed to determine if sufficient qualitative information is available to decide if the effect of the STI change on the PRA results would be negligible. If the qualitative information is not deemed sufficient for each contributor (internal events, fire events, seismic events, external hazards, and shutdown events) perform a bounding analysis as in Step 10b since external events and shutdown risk can be qualitative or quantitative.

Step 10b "Bounding Analysis Below 1E-07/yr ΔCDF and 1E-08/yr ΔLERF?" is entered from Step 10a if qualitative information has not proven sufficient for each contributor to provide to the IDP. Bounding analysis is performed on those SSCs that are represented in the PRA model at the initiating event, mitigating system, or functional level. The bounding effect on CDF and LERF resulting from the STI changes to the basic event value(s) are explored to determine the potential bounding impact of the STI change. If the CDF and LERF results from the STI change are not below the 1E-07/yr ΔCDF and 1E-08/yr ΔLERF limits, consider a revised STI value and proceed to Step 10c.

Step 10c "Revised STI Values Allow Bounding Analysis Below 1E-07/yr ΔCDF and 1E-08/yr ΔLERF?" is entered from Step 10b should Step 10b requirements not be met. Many times these bounding values are not met for the desired STI value but could be below the limits if a reduced STI change is considered. If this reduced STI path is chosen, the PRA model can be revised to model the STI change more explicitly. If the revised bounding analysis shows the STI change is below the limits for CDF and LERF, then proceed to Step 15 and provide the results to the IDP.

If the reduced STI change result is not below the limits for CDF and LERF, document that the STI cannot be changed and stop the process. At this point it may be possible to change the PRA model to model the STI change more explicitly to determine the CDF and LERF impacts. If this path is chosen, then proceed to Step 11.

Step 11 "Revise PRA Model as Needed" is entered from Step 9 when it the STI change can be modeled in the PRA or Step 10c when the STI change can be modeled in the PRA with model revisions when bounding analysis is not sufficient to support the STI change. The following actions are required:

- Make PRA model changes to represent the items in Step 8.
- Re-quantify base case CDF and LERF values based upon current STI values for the SSC being considered for changes.

Proceed to Step 12 upon completion of this step.

Step 12 "Evaluate total and Cumulative Effect on CDF and LERF" considers two types of effects on CDF and LERF in all PRAs. The first effect involves the total change to CDF and LERF results from all PRAs for individual STI changes, and the second effect involves the cumulative CDF and LERF changes from all STI changes. Further detail is provided in NEI 04-10.

Step 13 "Revise STI Values" is entered when it is determined that the Surveillance Frequency revisions do not meet the RG 1.174 acceptance criterion, are not supported by sensitivity study results (Step 14), or are not accepted by the IDP. The surveillance frequencies are adjusted accordingly and re-evaluated in Step 12.

Step 14 "Perform Sensitivity Studies" is performed by changing the unavailability terms for PRA basic events that correspond to SSCs being evaluated. This is accomplished by increasing the basic event failure probabilities of the SSCs with the proposed surveillance frequency by a factor of three. Simultaneously, adjust the corresponding common cause contribution by the same factor of three. Determine the CDF and LERF for the sensitivity case. No changes should be made to the base case.

If the sensitivity evaluations support the STI changes (i.e., RG 1.174 limits are still met), then go to Step 15. Alternatively, if the sensitivity evaluations show that the changes in CDF and LERF as a result of changes in SSCs being evaluated are not within the acceptance guidelines of RG 1.174, then revised frequencies should be considered (go to Step 13). However, it is acceptable to proceed with the STI change even if the results of the sensitivity studies are above the limits provided the base case results are below the limits. Qualitative considerations to the IDP will provide the confidence to proceed with the STI change in this instance.

Monitoring and feedback of the SSCs after the STI changes are implemented are valuable to determine that no additional failure mechanisms arise as a result of the STI change and the components maintain their function over time.

III. Risk-Evaluation Examples

This section provides examples of the three (3) aforementioned approaches (qualitative assessment, bounding analysis and quantitative assessment) used in internal event risk analysis of STI changes. Note that discussion and calculations shown in these examples only cover internal events. Fire, seismic, other external, and shutdown events must also be taken into consideration per NEI 04-10 guidance.

Qualitative assessment is performed when the SSCs associated with the STI changes are not explicitly modeled in the PRA. This assessment provides indication of the impact of the STI change on plant risk with no use of numerical values in the assessment.

Bounding assessment is performed when the SSCs associated with the STI changes are not explicitly included in the PRA model, but implicitly included in the model at the initiating event, mitigating system, or functional level. This assessment provides indication of the impact of the STI change on plant risk with use of some numerical values in the assessment.

Quantitative assessment is performed when the SSCs associated with the STI changes are (or can be) explicitly modeled in the PRA using a plant-specific or representative PRA model. This assessment provides numerical indication of the impact of the STI change on plant risk with change in CDF and change in LERF.

Qualitative Assessment Example – Containment Spray Additive System

The spray additive system is a subsystem of the containment spray system (CSS). It assists the CSS to remove airborne iodine fission product inventory in the containment atmosphere resulting from a design basis accident. The spray also helps control the pH level of the containment sump water. The risk evaluation was performed to assess the risk impact of extending the STI of the spray additive automatic valves from 18 months to 36 months. Since the spray additive system is not explicitly modeled in the PRA models, the impact on CDF and LERF from changing the test frequency of the spray additive valves cannot be quantified. As such, the qualitative assessment approach was used.

As previously noted the spray additive system assists the CSS in removal of airborne iodine fission products in containment and helps control the pH of the containment sump. As such, it provides no mitigating function related to core damage. Therefore, the STI change has no impact on CDF.

With respect to LERF, "large" release was defined using the NRC-accepted rule of thumb of two inch internal diameter of containment hole size that allows a 100 volume percent per day leak rate. "Early" release was defined as a core damage event which results in a containment release within 12 hours after event initiation and results in a containment release before the near site population can be evacuated following the declaration of a General Emergency. For PWRs, containment large and early release is from core damage sequences that result in the following large release modes:

- Large releases resulting from containment bypass: For these containment bypass events, the fission product releases are directly from the RCS, bypassing containment. As these events result in a direct pathway to the environment, the containment spray additive system has no impact on LERF for these events.
- Large releases resulting from failure of containment isolation: Containment isolation failures in the presence of any core damage event will result in a direct release to the environment due to failure of a containment penetration of a significant size to be considered "large." As earlier discussed, a leakage rate of one

containment volume per day is defined as a large release and a containment hole size of two inches can meet this criterion. Since the isolation failure will occur relatively early in the event, the benefit of scrubbing is marginal, but could be somewhat effective and benefit reducing the release. But the spray additive system only impacts iodine releases and not the overall size of the release. That is, a large release will still be a large release with or without the spray additive system. Therefore, it is concluded that failure of the spray additive system has no impact on LERF.

- Large releases resulting from energetic structural failure of containment: Events that result in an energetic structural failure generally include hydrogen burn, steam explosion, or direct containment heating. For containment failures related to high energy events, the containment sprays may be damaged, therefore, providing no benefits. For containment failures that occur at the time of reactor vessel failure because of high energy events, there may not be sufficient residence time for fission products in the containment for containment spray to be effective in reducing the release quantities. Per simplified Level 2 modeling guidelines, the sprays are generally not credited to avoid analysis complications in assessing the survivability and effectiveness of sprays following various high energy events. As a result, since the sprays provide little to no benefit, the spray additive system has no impact on determining LERF for these events. In addition, as noted above, the spray additive system only impacts iodine releases and not the overall size of the release. Therefore, it is concluded that the spray additive system has no impact on LERF.

Based on this discussion, it was concluded that since the spray additive system has no impact on CDF or LERF, changing the test frequency of the spray additive system will not impact the risk metrics and the proposed change is acceptable.

Bounding Analysis Example – Containment Airlocks

The containment air locks include a door on each side, which are interlocked to prevent simultaneous opening. The air lock interlock is designed to prevent simultaneous opening of both doors in a single air lock, forming part of the containment pressure boundary. Each air lock is provided with limit switches on both doors that provide control room indication of door position. Additionally, control room indication is provided to alert the operator whenever an air lock door interlock mechanism is defeated.

Since the containment air lock system is not explicitly modeled in the PRA models, the impact on CDF and LERF from changing the test frequency of the containment air locks cannot be quantified using the PRA model. As such, a bounding analysis is performed to assess the impact of the surveillance frequency changes on the risk metrics. The bounding analysis approach is consistent with Step 10 of NEI 04-10 methodology.

The risk evaluation was performed to assess the risk impact to extend the STI of containment air lock doors from 24 months to 48 months. As previously noted, the containment air locks form part of the containment pressure boundary and provide a means for personnel access to containment. As such, it provides no mitigating function related to core damage. Therefore, the following assessment is related only to LERF.

The bounding calculation assumes failure of the containment air lock interlock mechanism and both containment access doors are left open. These assumptions are conservative since they rely solely on the operators to react based upon control room alarm or door position indication. No other detection methods are credited in this calculation. In addition, no time fraction of the actual usage of the containment access doors is taken into account.

The LERF from failure of the containment air lock interlock mechanism is calculated as below:

$$\text{LERF}_{\text{from failure of interlock}} = \text{CDF}_{\text{bounding}} \times \text{Failure Probability}_{\text{interlock}} \times \text{HEP}_{\text{to leave both access doors open}}$$

A bounding CDF of 1.00E-04 per year is applied and a conservative value is assumed for the human error probability to leave both access doors open, given the failure of the air locks interlock.

The failure probability of the interlock mechanism was determined using the four events reported in an operating experience database over the last 10 years.

The delta or change in (Δ) LERF is calculated with the failure probability of the interlock mechanism doubled when extending the test interval from 24 months to 48 months resulting in a value of 4.00E-09/yr, which is less than 1E-08/yr, making the proposed change acceptable.

Sensitivity analyses for increased failure probabilities at the different containment air locks surveillance frequencies were completed consistent with Step 14 discussed in an earlier section. For the sensitivity, the failure probability of the interlock mechanism was increased by a factor of three. The sensitivity resulted in a ΔLERF of 2.00E-08/yr, which met the acceptance criteria in Step 10b.

Quantitative Analysis Example – Reactor Trip Breaker

The reactor trip breakers (RTBs) are in the electrical power supply line from the control rod drive motor generator set power supply to the control rod drive mechanisms (CRDMs). Opening of the RTBs interrupts power to the CRDMs, which allows the shutdown rods and control rods to fall into the core by gravity. The risk evaluation was performed to assess the internal event risk impact to extend the STI of the RTB from 2 months to 6 months.

Since the RTBs are explicitly modeled in PRA, the quantitative analysis approach was selected, using the representative plant fault tree model. The baseline CDF and LERF for the current STI were determined from fault tree quantification.

With the extended STI, the impacted parameters due to fewer tests are an increase (by a factor of three) of the RTB failure probability (including CCF), and a decrease (by a factor of three) of the RTB unavailability. The CDF and LERF were re-quantified with the new RTB failure probability and unavailability.

The risk impact was determined to be 4E-07/yr for ΔCDF and 1E-08/yr for ΔLERF. The ΔCDF and ΔLERF both met the acceptance criteria from Regulatory Guide 1.174 (1E-06/yr for ΔCDF and 1E-07/yr for ΔLERF) as discussed in earlier section.

Sensitivity analyses for increased failure probabilities at different RTB test intervals were completed consistent with Step 14 discussed in an earlier section. For the sensitivity, the random failure probability and common cause failures of the RTB were increased by a factor of three. The sensitivity resulted in 1.8E-06/yr for ΔCDF and 4.0E-08/yr for ΔLERF. The sensitivity study shows that ΔCDF was slightly higher than the acceptance criteria in Step 10b. However, since the base case assessment already met the acceptance criteria guideline, it was considered acceptable to proceed with the STI change with additional qualitative considerations provided. Qualitative considerations were mainly focused on margins, industry operating experience, and operating environment, which helped support that the STI change is still acceptable.

IV. CONCLUSIONS

Justification for extending surveillance test intervals for many systems, structures, and components can be realized through the application of the Reference 2 process. Three types of assessments are used in this justification that includes qualitative assessment, bounding assessment, and quantitative assessment with an example application for each provided.

Benefits of extending the TS surveillance frequency are directly related to the specific surveillance being addressed. For some surveillance frequency extensions there will be a reduction in engineering and technician time required to plan, perform, track, and report on the tests and results. Extension of other surveillances that are required to be completed during a refueling outage, such as the Engineered Safety Features (ESF)/Loss of Offsite Power (LOOP) surveillance and possibly transmitter calibrations, can lead to a reduction in outage time. Other benefits may include (but are not limited to) reduction in worker exposures and plant risk.

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REFERENCES

1. Regulatory Guide 1.174, Revision 2, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis,” May 2011.
2. NEI 04-10, Revision 1, “Risk-Informed Method for Control of Surveillance Frequencies,” April 2007.
3. Regulatory Guide 1.177, Revision 1, “An Approach for Plant-Specific, Risk-Informed Decisionmaking: Technical Specifications,” May 2011.