**An Approach for Determining the Limiting Set of Components for Which a License Renewal Applicant Should Consider the Effects of Reactor Water Environment**
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NUREG-1801 (GALL) Rev 2 and NUREG-1800 (LR-SRP) Rev 2 recommend identification of a limiting set of Reactor Coolant Pressure Boundary (RCPB) components for which a license renewal applicant should assess reactor water environmental fatigue effects. These components are used as sentinel locations for the Fatigue Monitoring Program to monitor environmentally assisted fatigue. A Fatigue Monitoring Program is used to monitor, track and establish remedial actions necessary to manage fatigue usage of reactor coolant pressure boundary components.

> For purposes of monitoring and tracking, applicants should include for a set of sample reactor coolant system components, fatigue usage calculations that consider the effects of the reactor water environment. This sample set should include the locations identified in NUREG/CR-6260, as a minimum, and additional plant specific component locations in the reactor coolant pressure boundary if they may be more limiting than those considered in NUREG/CR-6260. [NUREG-1801 X.M1 element 1]

For both PWR and BWR plants, NUREG/CR-6260 components are not necessarily the locations with the highest design Cumulative Usage Factors (CUFs) in the plant, but were component locations chosen to give a representative overview of components that had higher CUFs or were important from a risk perspective. For example, the reactor vessel shell (and lower head) was chosen for its risk importance. The population of RCPB components that are evaluated to identify the limiting set of components are comprised of major components (e.g., Reactor Pressure Vessel, Pressurizer, Steam Generator, Suppression Pool) and Class 1 piping systems. Major components consist of subcomponents, which for this discussion will be called components. Piping systems are comprised of components. The limiting fatigue location in a component may be a section (NB-3200 analysis) or the component as a whole (NB-3600 analysis)

For a newer vintage 4 loop Westinghouse PWR the NUREG/CR-6260 components include:

- RPV Bottom Head to Shell Junction
- RPV Inlet Nozzle
- RPV Outlet Nozzle
- Hot Leg Surge Nozzle
- Charging System Nozzle
- Safety Injection Nozzle
- RHR Inlet Nozzle

For a newer vintage BWR the NUREG/CR-6260 components include:

- Reactor Vessel Shell and Lower Head
- Reactor Vessel Feedwater Nozzle
- Reactor Recirculation Piping (Including inlet and Outlet Nozzles)

- Core Spray Line Reactor Vessel Nozzle
- Residual Heat Removal Nozzles
- Feedwater Class 1 Piping

Each ASME Class 1 component qualification is documented in the design report/stress report for the component. As part of the Class 1 analysis of components, fatigue is evaluated when cyclic loads exceed the fatigue screening criteria provided by the ASME Code. Original plant design practice for older plants determined a bounding cumulative usage factor based upon consideration of bounding cyclic conditions. This past practice has included conservative assessments of loading conditions and expected cycles. These analysis methods often lead to a bounding cumulative fatigue usage (CUF) that may not actually be the controlling location when reactor water environmental effects on fatigue are considered. Thermal transients experience strain rates that have higher impacts on the values of the environmental correction factor; while cyclic dynamic loads are accompanied by higher strain rates with little impact on the environmental correction factor. Therefore, when evaluating for impact of environmental effects on fatigue it is necessary to focus on components where fatigue usage is governed by thermal transients rather than cyclic dynamic loads such as seismic or hydrodynamic loading events.

The following approach is a method for determining the limiting set of components for which a license renewal applicant should consider the effects of reactor water environment on fatigue. This is one approach to determine the limiting set of components, other approaches may be developed in the future. The Fatigue Monitoring Program should track the transients affecting fatigue usage for these limiting components. This approach applies to all Reactor Coolant Pressure Boundary components in a reactor water environment (surfaces are wetted with reactor water). The intent is not to update all fatigue calculations, but to establish decision criteria for identifying locations that are most susceptible to reactor water environment fatigue effects. The Fatigue Monitoring Program would incorporate the limiting components and assumptions associated with the analysis as part of program's approach to managing the effects of aging due to fatigue usage.

1. Identify all design CUFs in the applicable design reports/stress reports for each piping system and major component in the RCPB (excludes reactor internals). Within each design report/stress report identify the component locations that contact reactor coolant. These locations will be considered in the steps below. For each piping system and major component group, identify the design transients used in each analysis.

2. For older plants with piping systems that do not have an ASME Section III fatigue analysis perform the following:
    a. Identify the NUREG/CR-6260 components that do not have an ASME Section III fatigue analysis.
    b. For each of the systems in which these NUREG/CR-6260 components reside, identify the component with the highest temperature and stress range for normal and upset conditions.

c. Perform an NB-3200 or NB-3600 analysis for the component. This analysis will be used to determine the CUF for the limiting location and compute the $CUF_{en}$ (environmentally-adjusted cumulative usage factor) for that location of the component.

3. For each piping system and major component, determine the maximum environmental fatigue correction factor ($F_{en}$). Correction factors are determined using formulae in NUREG/CR-6909 for the applicable material. Formula in NUREG/CR-6583 (carbon and low alloy steel) and NUREG/CR-5704 (stainless steel may also be used. For nickel alloy material, only NUREG/CR-6909 may be used to determine the $F_{en}$. A staff approved alternative may also be used.
   a. Use average temperature applicable to that location (maximum temperature when using NUREG/CR-6583 and NUREG/CR-5704)
   b. Use actual dissolved oxygen concentration at the component. If more than one value is applicable for different time periods, compute separate $F_{en}$ values and apply those using appropriate time-weighted factors.
   c. Use strain rate that would maximize the $F_{en}$

4. From the design report/stress report or fatigue analysis for each major component or piping system identify the components or locations within the component with the maximum fatigue usage and multiply the CUF by the $F_{en}$ to calculate the fatigue usage factor corrected for environmental effects ($CUF_{en}$ ) for each different material within the component using the maximized $F_{en}$ from step 3.

5. If $CUF_{en}$ is less than 1.0 then no refinement of the $CUF_{en}$ calculation is necessary.

6. If a maximum $CUF_{en}$ is greater than 1.0, then review the associated analysis to identify load pairs with strain amplitudes below the strain threshold or resulting from transients with a high, effective strain rate and therefore lower effective $F_{en}$. Using the maximum $CUF_{en}$ calculated in step 4 for each major component or piping system, recalculate the $CUF_{en}$s using a strain-rate-dependent $F_{en}$. The component in each major component or piping system with the maximum strain-rate-dependent $CUF_{en}$ will become a limiting plant specific component. These results will replace those obtained in step 4.

7. The results in steps 4 and 6 yield a maximum $CUF_{en}$ for each piping system and major component including systems that are not included in the NUREG/CR-6260 locations. Augment the NUREG/CR-6260 locations with the limiting locations identified in steps 4 and 6 above that are not NUREG/CR-6260 locations. This will be the list of plant-specific limiting locations.

8. For the components identified in step 7 with $CUF_{en}$s greater than 1.0, perform a detailed $CUF_{en}$ analysis using a plant-specific reduced number of cycles for transient pairs with significant contribution to fatigue.

NOTE:

Section 6.4 of NUREG/CR-6260 advises that conservative assumptions remain which could be removed to reduce the $CUF_{en}$ values. One method to lower the $CUF_{en}$ for the high $CUF_{en}$ locations is fatigue monitoring. By using actual numbers of cycles and severity of transients, the calculated $CUF_{en}$ can in most cases be reduced to meet the 1.0 allowable.

9. For all $CUF_{en}$s calculated in step 8 greater than 1.0, perform an NB-3200 or NB-3600 analysis using a plant-specific reduced number of cycles for transient pairs with significant contribution to fatigue. The reduced number of transient cycles is based on plant specific accumulation data and will be used to set action limits in the Fatigue Monitoring Program. Actual transient severity can also be used to further reduce the calculated CUF value.