### AMP 101 LOW CYCLE FATIGUE MONITORING (Version 2020)

### Programme Description

This programme manages low-cycle fatigue effects of thermal and pressure cyclic transients considered in the nuclear plant design basis or included in its licensing basis during the plant operating life. Also included are transients (under control or investigation) due to the occurrence of fluid conditions having the potential for inducing cyclic thermal stresses like thermally stratified flow occurring for example in pressurizer surge lines [1, 2]. It applies to components (including but not limited to mechanical equipment and piping) subject to cyclic loading as described above [3-9].

Fatigue cumulative usage factor (CUF) is a computed parameter suitable for evaluating fatigue damage in components subjected to fluctuating stresses. As a design limit for fatigue, a CUF of 1.0 is generally taken. Different CUF limits may also be used for other purposes, such as to determine locations which do not need to be considered for high energy line break mitigation.

In order not to exceed the design limit on fatigue usage, this programme monitors and tracks the number of critical thermal and pressure transients for the selected components. Critical transients are those that cause cyclic strain, which are significant contributors to the fatigue usage factor. In the case of monitoring anticipated transients (e.g. from plant design basis), the programme also verifies that the severity of each monitored transient is bounded by the design transient definition for which it is classified. In some countries, monitoring of the transients in the plant’s current licensing basis is a requirement of national regulations (e.g., [10]) or national standards (e.g., [11, 12]) or plant technical specifications (e.g., [13]).

The fatigue evaluation process may identify threshold values for the CUF above which corrective actions (changes in operating procedures, non-destructive examination, component repair, replacement, or reanalysis, etc.) are considered prior to the CUF exceeding the design limit.

The evaluation of low cycle fatigue is addressed in TLAA 101.

The procedures for fatigue monitoring combine transient logging and fatigue usage monitoring. One approach for this monitoring could be where the plant events are recognized by a set of rules which correlates data (temperature, pressure, flow rate, valve status, electric signals, etc.) collected from plant process computers or from additional instrumentation. Several computer programmes for such transient logging and fatigue usage monitoring are available and can be combined to improve the efficiency of the programme.

This ageing management programme may address the effects of the reactor coolant environment on component fatigue life (to determine an environmentally-adjusted cumulative usage factor, or CUFen) by assessing the impact of the reactor coolant environment on a set of sample critical components for its plant-specific configuration [13-16]. An overview of approaches used by different countries (US, France, Finland, Japan and Germany) to account for environmental effects on fatigue is given in [17]. The evaluation of environmentally assisted fatigue is addressed in TLAA 106.

Periodic reviews of the programme may lead to the inclusion or suppression of transients or locations to be considered in fatigue evaluations. Justifications are documented and readily available to applicable regulatory review.

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### Evaluation and Technical Basis

1. ***Scope of the ageing management programme based on understanding ageing:***

The scope includes those components subject to the occurrence of fluid conditions having the potential for inducing cyclic thermal and/or pressure stresses.

The programme monitors and tracks those transients for the selected locations to ensure that the fatigue cumulative usage factor remains within the allowable limit, thus minimizing fatigue damage of metal components caused by cyclic stresses.

The programme may also evaluate, for a set of sample reactor coolant system locations, fatigue usage factors that consider the effects of the reactor coolant environment. Those sample locations are plant-specific.

Monitoring anticipated cyclic transients encompasses the following activities [18]:

* Characterization of the plant fatigue licensing basis (transient descriptions, considering severity, and number of occurrences);
* Data collection (temperature, pressure, flow rate, etc), at selected locations, to characterize actual operational transients in severity and number of occurrences. In order to ensure adequate performance of the sensors and transmitters used for data collection, AMP 217 may be considered;
* To ensure that either the total number of transient occurrences is less than the design number, or, when the design number of occurrences is exceeded for some transients, the CUF remains below 1;
* To ensure that the actual transient loads are bounded by those for the licensing basis transients;
* Reconciliation and corrective actions for cases in which the licensing basis assumptions are exceeded by the actual operational transients.

Monitoring new unanticipated cyclic transients demands a case by case study to define the parameters to be monitored, the viable sensor types, the locations for the installation of sensors, the monitoring frequency, the possibility of metal fatigue, and the hardware and software to be used for data collection and fatigue assessments [19].

During plant operation, the programme scope can be reduced, if selected transients or locations under control are shown not to be relevant or enlarged to investigate new locations potentially subject to low-cycle fatigue; to respond to recommendations from operating experience; or to comply with additional regulatory requirements.

1. ***Preventive actions to minimize and control ageing degradation:***

The programme prevents the current fatigue analyses from becoming invalid by assuring that the fatigue usage factor resulting from actual operational transients does not exceed the design limit, including anticipated and new unanticipated transients, and environmental effects where applicable. In the case of monitoring anticipated transients, this could be caused by the numbers of actual plant transients exceeding the numbers used in the existing fatigue analyses or by the actual transient severity exceeding the bounds of the design transient definitions. However, in either of these cases, the programme remains effective if the analysis is revised to account for the increased number or severity of transients such that the value of the cumulative usage factor remains below the design limit.

1. ***Detection of ageing effects:***

In general, fatigue monitoring is a preventive programme and does not directly detect ageing effects. The programme provides for updates of the fatigue usage calculations on an as-needed basis if an allowable cycle limit is approached, or in a case where a transient definition has been changed, new unanticipated thermal or pressure events are discovered, or the geometry of components have been modified. In some countries, corrective actions are required for locations in which the CUF exceeds a threshold value below the design code limit.

1. ***Monitoring and trending of ageing effects:***

CUF of typical locations subjected to low-cycle fatigue is monitored. Trending is utilized to ensure that the fatigue usage factor remains below the design limit during all plant operating periods, thus minimizing fatigue damage of metal components caused by cyclic strains in the material. Projections of future transient occurrences, in combination with action limits on CUF values, can provide assurance that corrective actions will be made prior to the CUF exceeding the design limit.

1. ***Mitigating ageing effects:***

Fatigue monitoring is a preventive ageing management programme, and no specific mitigating actions are provided. In some cases, mitigation of fatigue can occur through improved operational procedures or equipment replacement to reduce transient occurrences or severity, for example mitigation of thermal shock in steam generator feeding through replacement of feed water valves by better controlled ones.

Mitigation of thermal stratification can be performed by hardware modifications (for instance the replacement of feed water valves for better feeding of the steam generators) or by modification in operational regimes (for example during startup and shutdown when thermal stratification may occur).

1. ***Acceptance criteria:***

The acceptance criterion is maintaining the fatigue cumulative usage factor below the design limit through all plant operating periods, with consideration, where applicable, of the reactor coolant environmental fatigue effects mentioned in the programme description and scope of programme. Maintaining the CUF below the design limit is achieved by ensuring that cycle counts remain below design limits, operational transient loads are bounded by design transients, and the use of action limits to initiate corrective actions prior to exceeding the design limit. For situations where the CUF may exceed 1.0, flaw tolerance evaluations such as Appendix L of the ASME Code [21] may be used to assess continued acceptability.

1. ***Corrective actions:***

The programme provides for corrective actions to prevent the usage factor from exceeding the design code limit during plant operating periods. Acceptable corrective actions may include repair or replacement of components, design modifications, revision of operating procedures, performance of non-destructive examinations supported by crack growth analysis, and more rigorous analysis to demonstrate that the design code limit will not be exceeded during the plant operating periods. However, some guidelines, such as [20] for example, require non-destructive testing to confirm absence of cracking due to fatigue, for locations that have a CUF exceeding 0.8, i.e. prior to reaching the design code limit. Scope expansion includes consideration of additional transients or other locations, for example, with highest expected cumulative usage factors when considering environmental effects.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

Fatigue monitoring is a preventive programme and does not directly detect ageing effects. The programme reviews industry experience relevant to fatigue. Applicable operating experience relevant to low cycle fatigue is to be considered in selecting transients and locations for monitoring. Unanticipated loadings such as thermal stratification have been identified and have been used to update the programmes [19, 22]. Operating experience in different countries regarding monitoring of transients that were initially not in the plant’s design basis may be found in [23-28].

At the time when this AMP was produced, no relevant R&D was identified.

1. ***Quality management:***

Administrative controls, quality assurance procedures, review and approval processes, are implemented in accordance with the different national regulatory requirements (e.g., 10 CFR 50, Appendix B [29]).

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