## AMP 120 SELECTIVE LEACHING (VERSION 2020)

**Programme Description**

The programme for selective leaching (dealloying) of materials ensures the integrity of the components made of gray cast iron, ductile iron, and copper alloys (except for inhibited brass) that contain greater than 15 percent zinc or 8 percent aluminum exposed to a raw water, closed-cycle cooling water (CCCW), treated water, waste water, soil, or groundwater environment. Depending on the environment, the AMP includes one-time, or opportunistic or periodic visual inspections of selected components that are susceptible to selective leaching, coupled with mechanical examination techniques (e.g., chipping, scraping). Destructive examinations of components to determine the presence of and depth of dealloying through wall thickness are also conducted. These techniques can determine whether loss of material due to selective leaching is occurring and whether selective leaching will affect the ability of the components to perform their intended function for the intended period of operation.

Susceptible materials, high temperatures, stagnant-flow conditions, and a corrosive environment, such as acidic solutions for brasses with high zinc content and dissolved oxygen, are conducive to selective leaching [1-2, 10, 14]. The selective leaching process involves the preferential removal of one of the alloying components from the material. Dezincification (loss of zinc from brass) and graphitic corrosion (removal of iron from gray cast iron and ductile iron) are examples of such a process. A de-alloyed component often retains its shape and may visually appear to be unaffected; however, the functional cross-section of the material has been reduced. The ageing effect attributed to selective leaching is loss of material because the affected volume has a permanent change in density and does not retain mechanical properties that can be credited for structural integrity.

### Evaluation and Technical Basis

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

The programme for selective leaching (dealloying) of materials ensures the integrity of the components made of gray cast iron, ductile iron, and copper alloys (except for inhibited brass) that contain greater than 15 percent zinc or 8 percent aluminum exposed to a raw water, closed-cycle cooling water (CCCW), treated water, waste water, soil, or groundwater environment. Components include piping, valve bodies and bonnets, pump casings, and heat exchanger components.

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

Although the programme does not provide guidance on preventive actions, it is noted that monitoring of water chemistry to control pH and concentration of corrosive contaminants and treatment to minimize dissolved oxygen in water are effective in reducing selective leaching. Water chemistry is managed by the AMP 103.

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

Inspections, where possible, focus on the bounding components, or those considered the most susceptible to ageing, based on time-in-service and severity of operating conditions for each population. One-time and periodic inspections are conducted of a representative sample of each population. A population is defined as the same material and environment combination.

One-time inspections are only conducted for components exposed to CCCW or treated water when no plant-specific OE of selective leaching exists in these environments.

Opportunistic and periodic inspections are conducted for components exposed to raw water, waste water, soil, or groundwater and for components in CCCW or treated water where plant-specific OE includes selective leaching in these environments. Opportunistic inspections are conducted whenever components are opened or whenever buried or submerged surfaces are exposed. Periodic inspections are conducted according to the plant specific evaluations and national regulatory requirements

Selective leaching can be detected through assessment of visual appearance (color, porosity, abnormal surface conditions) and possibly through surface hardness measurements [10, 13]. Because selective leaching is a slow acting corrosion process, this measurement is performed within 5 years prior to entering the period of long term operation. Follow-up of unacceptable inspection findings includes an evaluation using the corrective action programme and a possible expansion of the inspection sample size and location.

Where practical, the inspection includes a representative sample of the system and focuses on the bounding components, or those considered the most susceptible to selective leaching due to time-in-service, severity of operating conditions, and lowest design margin [3]. Twenty percent of the population with a maximum sample of 25 constitutes a representative sample size. Otherwise, a technical justification of the methodology and sample size used for selecting components for the one-time inspection is included as part of the programme’s documentation. Each group of components with different material/environment combinations is considered a separate population. For subsequent inspections following this one-time inspection or initial inspections, a reduction in sampling may be technically justified as discussed in [4]. Reduced sampling guidance for components is further described in [5].

Selective leaching generally does not cause changes in dimensions and is difficult to detect by visual inspection. However, in certain brasses, it may lead to discoloration that can be detected visually [10, 14].

For most copper-zinc alloys, selective leaching causes a discoloration from normal yellow to reddish copper coloring [6, 10, 14]. Due to dezincification, a relatively weak and porous layer of copper and copper oxides forms which results in local decrease of hardness. Discoloration is not reliably visible for gray cast iron components [10, 14]. One acceptable procedure is to visually inspect the susceptible components closely and conduct hardness testing (where feasible, based on form and configuration or other industry-accepted mechanical inspection techniques) on the susceptible surface(s) of the selected set of components to determine if selective leaching has occurred [10, 13]. If selective leaching is apparent, an engineering evaluation is initiated to determine acceptability of the affected components for further service, and periodic inspections are conducted to ensure adequate ageing management.

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

Where practical, results of periodic inspections are trended in order to project observed degradation to the end of intended period of operation or the next scheduled inspection, whichever is shorter. Corrective actions are taken when trending results project that a loss of intended function could occur prior to the next inspection.

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

This programme is a condition monitoring programme and does not mitigate selective leaching effects. However, since selective leaching is dependent on environmental conditions and presence of a susceptible material, mitigative actions can be made regarding the environment (decrease of the oxygen level and increase of the pH) and the materials (selection of non-susceptible materials in the design phase or upon replacement).

1. ***Acceptance criteria:***

The acceptance criteria are: (a) for copper-zinc alloys, no noticeable change in color from the normal yellow color to the reddish copper color or green copper oxide; (b) for copper-aluminum alloys, no change in the normal yellow color to the green color of copper oxide in conjunction with no indication of selective leaching when a suitable chemical etchant is applied to the surface. Visual inspections using only component color may not be sufficient to demonstrate the absence of selective leaching [10]; (c) gray cast iron and ductile iron, the absence of a surface layer that can be easily removed by chipping or scraping or identified in the destructive examinations.

The presence of a superficial layer of dealloying, as determined through appropriate nondestructive methods or by removal of the dealloyed material by mechanical removal, meets acceptance criteria, and (d) the components meet system design requirements such as minimum wall thickness, when extended to the end of the intended period of operation. When evaluating a component in relation to criterion (d) no credit is used for the material properties of the dealloyed portion of the component.

1. ***Corrective actions:***

Engineering evaluations are performed for test or inspection results that do not satisfy established acceptance criteria. Corrective actions are accomplished through the plant’s corrective actions programme to ensure that conditions adverse to quality are promptly corrected. If the deficiency is assessed to be significantly adverse to quality, the cause of the condition is determined and an action plan is developed to preclude repetition. Unacceptable inspection findings result in additional inspection(s) being performed, which may be on a periodic basis, or in component repair or replacement.

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.

Selective leaching has been detected in components constructed from cast iron, brass, bronze, ductile iron and aluminum bronze (e.g., [5, 7-8, 10, 14]). Affected components have included valve bodies, pump casings, piping, and cast-iron fire protection piping buried in soil. The elements that comprise the inspections (e.g., the scope of the inspections and inspection techniques) are consistent with industry practice and guidance from the appropriate regulatory body.

Appropriate sources of external operating experience are e.g. Owner’s Groups, OECD-NEA, WANO, INPO, IAEA, EPRI and NRC generic communications.

The mechanical hardness in regions of a component damaged by selective leaching is substantially less than for the remaining, undamaged regions of the component. Hardness testing can generally discriminate between points on the surface of a component affected by selective leaching and those that remain nominal if accurate methods are used. However, point measurements of the surface hardness of a component are indicative of only the location where the measurement was made and should not be used alone to generalize the state of component health in the surrounding regions. Additionally, research conducted at EPRI suggests that hardness values indicating the presence of selective leaching should not be used alone to gauge the depth of the selective leaching damage [10, 13].

Best practices and guidance for procedural development to nondestructively detect and characterize selective leaching for gray cast iron, and aluminum bronze was developed by EPRI and contained in [9]. This report includes three different nondestructive techniques for detecting and characterizing selective leaching were developed. Each technique is a form of ultrasonic examination technology, including normal-beam ultrasonics, phased array ultrasonics, and time-of-flight diffraction (an angle-beam ultrasonic technique). Other research conducted at EPRI using ultrasonic and other nondestructive methods is contained in [10, 15].

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

1. ***Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with different national regulatory requirements (e.g., 10 CFR Part 50, Appendix B, [6]).

**References**

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