ATTACHMENT (7)

CORROSION EVALUATION FOR PRESSURIZER HEATER SLEEVE REPAIR – NON-PROPRIETARY

Calvert Cliffs Nuclear Power Plant, LLC
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AREVA

AREVA NP Inc.

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Corrosion Evaluation for Calvert Cliffs Unit 2 Pressurizer Heater Sleeve Repair

Safety Related? ☒ YES ☐ NO

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1.0 BACKGROUND

Note: The AREVA NP "Proprietary" version of this document is 51-9156066-000. The AREVA NP Proprietary information is removed from this non-proprietary document as indicated by "{ }".

All 120 Alloy 600 pressurizer heater sleeves at Calvert Cliffs Nuclear Power Plant Unit 2 (CCNPP-2) were repaired in 1990. The 1990 repair configuration is described in References 1 and 2. 119 heater sleeves were replaced with Alloy 690 heater sleeves, each consisting of an outer sleeve and an inner sleeve. Since the inner sleeve is irrelevant to this evaluation, only the Alloy 690 outer sleeve is discussed in this document. The Alloy 690 outer sleeve illustrated in Figure 2-1 for the 1990 repair is hereafter referred to as "sleeve". The remaining H3 location was plugged with one oversized Alloy 690 sleeve and an Alloy 690 plug as illustrated in Figure 2-2. At each of the 120 locations, an Alloy 82 weld pad was built up on the outside surface of the bottom head. The Alloy 690 sleeve was attached to the weld pad with an Alloy 82 partial penetration weld on the outside surface of the bottom head. On the inside surface (i.e., cladding surface) of the pressurizer bottom head, an autogenous weld was used to seal the annular crevice between the Alloy 690 sleeve and penetration at each location.

In February 2011, the Alloy 82 partial penetration weld at heater sleeve N3 location was found leaking reactor coolant system (RCS) water. {

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2.0 SCOPE

This document evaluates the following corrosion concerns for the 1990 heater sleeve repair and the proposed repair at the N3 heater location in 2011:

1. Corrosion evaluation of the low alloy steel (LAS) base metal of the pressurizer bottom head (SA-533, Grade B, Class 1)[3] exposed to the RCS water. (Sections 3 and 4)
    a. General Corrosion
    b. Crevice Corrosion
    c. Galvanic Corrosion
    d. Stress Corrosion Cracking
    e. Hydrogen Embrittlement

    The exposed LAS base metal locations are shown as Locations A, B, and C in Figure 2-1, Figure 2-2, and Figure 2-3.

    - The exposed LAS { }
    - The exposed LAS { }
    - The exposed LAS { }
2. Corrosion evaluation of Alloy 690 and Alloy 52M for the proposed N3 repair shown in Figure 2-3. (Section 5)

Note: The following are not covered by this document:

- Corrosion evaluation for the remaining Alloy 82 weld pad after the proposed N3 heater sleeve repair.
- Corrosion evaluation for the 1990 repair of heater sleeves, except for the corrosion evaluation of the exposed LAS base metal.

{ }

Figure 2-1: 1990 Heater Sleeve Repair Configuration (except H3 location) [2]

(Note: only the outer sleeve is shown for the 1990 repair)

{ }

Figure 2-2: 1990 Repair Configuration at H3 Heater Sleeve Location [2]

{ }

Figure 2-3: Proposed N3 Repair [4]

3.0 INDUSTRY OCCURRENCES OF EXPOSED CARBON/LOW ALLOY STEEL BASE METAL

The carbon or LAS components in the pressurizer, reactor vessel, and the steam generator exposed to PWR RCS primary coolant are clad with either stainless steel or nickel-base alloy in order to prevent corrosion of the carbon or LAS base metal. Throughout the operating history of domestic PWRs, there have been many cases where a localized area of the carbon or LAS base metal has been exposed to the PWR RCS primary coolant due to damage to the cladding or repair configuration. Several such instances are listed below:

{

}

4.0 CORROSION OF LOW ALLOY STEEL EXPOSED TO RCS

Several types of corrosion can potentially occur when carbon and LAS base metal are exposed to primary coolant. During operation, the primary coolant is deaerated and at ~650°F in the pressurizer. During normal operation the primary coolant inside Locations A, B, and C will be stagnant. During shutdown, the primary coolant temperature is at 70-100°F and may become aerated. The following subsections discuss the potential corrosion mechanisms for the exposed LAS base metal at Locations A, B, and C.

4.1 General Corrosion

General corrosion is defined as uniform deterioration of a surface by chemical or electrochemical reactions with the environment. Austenitic stainless steels and nickel-base alloys (e.g. wrought Type 304, Type 316, Alloy 600, and Alloy 690 materials and their equivalent weld metals) are virtually immune to general corrosion from exposure to PWR primary coolant. Carbon and LAS, however, may be subject to general corrosion upon exposure to primary coolant. The general corrosion rates of carbon and LAS during aerated and deaerated reactor coolant conditions are discussed below.

4.1.1 General Corrosion Data

{

}

4.1.2 Pressure Boundary Leakage (Wastage)

{

}

4.1.3 General Corrosion Rate for Locations A, B and C

{

}

Table 4-1: Combined Average Corrosion Rate for Stagnant or Low Flow Conditions

Operating Condition 24 month cycle	Shutdown Condition 2 month cycle	**Combined Average Corrosion Rate**
{ }	{ }	{ }

4.1.4 Long Term General Corrosion

The corrosion rate of the exposed LAS at Locations A, B and C is conservatively estimated to { } for a 24-month fuel cycle (24-month operation followed by a 2-month shutdown) as described above. The Fe release rate into the RCS water from these locations is evaluated below.

<u>Location A</u>

{

}

<u>Location B</u>

{

}

Location C

{

}

4.2 Crevice Corrosion

{

}

4.3 Galvanic Corrosion

{

}

4.4 Stress Corrosion Cracking

Stress corrosion cracking (SCC) can occur only when the following three conditions are present: (1) a susceptible material, (2) a tensile stress, (3) and an aggressive environment.

{

}

4.5 Hydrogen Embrittlement

{

}

5.0 CORROSION OF ALLOYS 690/52M

The corrosion resistance of Alloy 690 and weld metal Alloys 52 and 152 has been extensively studied as a result of numerous PWSCC failures in mill annealed Alloy 600 and weld metals Alloys 82 and 182 in primary water environments. As a result of Alloy 600 and Alloys 82 and 182 failures, Alloy 690 and Alloys 52 and 152 have been chosen by the nuclear power industry as the replacement material of choice for Alloy 600 and Alloy 82 and 182 components and welds in PWRs. Alloy 52M, a modified version of Alloy 52 for improved weldability, is the same as Alloy 52 in terms of the corrosion resistance properties discussed below.

5.1 SCC Resistance: Near Normal Conditions

{

}

5.2 SCC Resistance: Extreme Conditions

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}

5.3 Hydrogen Effects

{

}

6.0 SUMMARY

The preceding sections have evaluated the potential corrosion mechanisms affecting the exposed LAS in the 1990 heater sleeve repair and the proposed N3 pressurizer heater sleeve repair in 2011 for the CCNPP-2 pressurizer.

For the LAS exposed to the primary coolant, galvanic corrosion, hydrogen embrittlement, SCC, and crevice corrosion are not expected to be a concern. Based on industry data and AREVA NP's experience, the general corrosion rate of exposed LAS at Locations A, B and C is conservatively estimated to { } for a 24-month fuel cycle (24-month operation followed by a 2-month shutdown). Due to the { } at Location A is expected to be quickly { }. The exposed area at Locations B and C are very small with the combined estimated Fe release rate of { }.

Wrought Alloy 690 has been shown to exhibit superior PWSCC resistance by extensive laboratory testing and in-reactor operating experience. There have been no reports of in-service failures of { }. No cracking of Alloy 690 has been observed, even for oxygenated conditions { }. However, cracking of Alloy 690 is possible under more extreme environmental conditions not found in PWRs. Alloys 52 and 152 have also been shown to exhibit superior PWSCC resistance compared to Alloys 82 and 182, particularly { }. The Alloy 690 and its weld metal Alloy 52M used for the proposed N3 repair are not likely to degrade from exposure to the primary coolant during the remainder of the service life at CCNPP-2.

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