ATTACHMENT 1

MRP-227-A Applicant/Licensee Action Item 6 Analysis for the
Oconee Nuclear Station Units 1, 2, and 3;
ANP-3477NP (Rev. 0);
[Non-Proprietary]

AREVA

MRP-227-A Applicant/Licensee Action Item 6 Analysis for the Oconee Nuclear Station Units 1, 2, and 3

ANP-3477NP
Revision 0

Licensing Report

May 2016

AREVA Inc.

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

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Nomenclature

Acronym	Definition
A/LAI	Applicant/Licensee Action Item
B&W	Babcock & Wilcox
B-B	Baffle-to-Baffle
B-F	Baffle-to-Former
CB	Core Barrel
CBA	Core Barrel Assembly
CB-F	Core Barrel-to-Former
CW	Cold-Worked
dpa	Displacements Per Atom
EPRI	Electric Power Research Institute
I&E	Inspection and Evaluation
IASCC	Irradiation-Assisted Stress Corrosion Cracking
IE	Irradiation Embrittlement
ISR/IC	Irradiation-Enhanced Stress Relaxation/Irradiation Creep
LWR	Light Water Reactor
MeV	Mega electron Volt
MRP	Materials Reliability Program
NDE	Non-Destructive Examination
NRC	Nuclear Regulatory Commission
ONS	Oconee Nuclear Station Units 1, 2, and 3
PT	Dye-Penetrant Test(ing)
PWR	Pressurized Water Reactor
RT	Radiographic Testing
SCC	Stress Corrosion Cracking
SER	Safety Evaluation Report
U.S.	United States
UT	Ultrasonic Testing
VS	Void Swelling
VT-3	Visual Testing method (defined in ASME Code Section XI)

ABSTRACT

This document addresses applicant/licensee action item 6 from MRP-227-A for Oconee Nuclear Station Units 1, 2, and 3. Note that, through the entirety of this report, "ONS" will refer to all three units, unless otherwise noted. Evaluations are included herein that justify the acceptability of the following inaccessible or non-inspectable reactor vessel internals component items for continued operation through the period of extended operation:

- Core barrel cylinder (including the vertical and circumferential seam welds), which is susceptible to a reduction in toughness due to irradiation embrittlement (Section 4.0)
- Former plates, which are susceptible to a reduction in toughness due to irradiation embrittlement (Section 5.0)
- Applicable core barrel assembly bolting (i.e., internal baffle-to-baffle bolts, external baffle-to-baffle bolts and the associated locking devices and locking welds, and the core barrel-to-former bolts and the associated locking devices and locking welds), which are susceptible to multiple age-related degradation mechanisms (Section 6.0)

1.0 INTRODUCTION AND PURPOSE

The Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) developed inspection and evaluation (I&E) guidelines in MRP-227-A [1] for managing the long-term aging of reactor vessel internal component items of pressurized water reactors (PWRs). The I&E guidelines define requirements for inspections that will allow owners of PWRs to demonstrate that the effects of age-related degradation are adequately managed for the period of extended operation.

MRP-227-A includes a safety evaluation report (SER) prepared by the United States (U.S.) Nuclear Regulatory Commission (NRC). The NRC staff determined whether the guidance ensured that the reactor vessel internal component items will maintain their intended functions during the period of extended operation. From the determination, seven (7) topical report conditions and eight (8) plant-specific applicant/licensee action items (A/LAIs) were contained in the SER to alleviate issues and concerns of the NRC staff. The plant-specific A/LAIs address topics related to the implementation of MRP-227-A that could not be effectively addressed on a generic basis. A/LAI 6 addresses the NRC staff concerns regarding inaccessible or non-inspectable component items. A/LAI 6 reads as follows:

> *As addressed in Section 3.3.6 in this SE, MRP-227 does not propose to inspect the following inaccessible components: the B&W core barrel cylinders (including vertical and circumferential seam welds), B&W former plates, B&W external baffle-to-baffle bolts and their locking devices, B&W core barrel-to-former bolts and their locking devices, and B&W core barrel assembly internal baffle-to-baffle bolts. The MRP also identified that although the B&W core barrel assembly internal baffle-to-baffle bolts are accessible, the bolts are non-inspectable using currently available examination techniques.*

Applicants/licensees shall justify the acceptability of these components for continued operation through the period of extended operation by performing an evaluation, or by proposing a scheduled replacement of the components. As part of their application to implement the approved version of MRP-227, applicants/licensees shall provide their justification for the continued operability of each of the inaccessible components and, if necessary, provide their plan for the replacement of the components for NRC review and approval.

This document will address the applicable component items to fulfill A/LAI 6 of MRP-227-A for Duke Energy's Oconee Nuclear Station (ONS) Units 1, 2, and 3. The applicable component items are as follows:

- Core barrel (CB) cylinder, which includes the vertical and circumferential seam welds
- Former plates
- Applicable core barrel assembly (CBA) bolting, which includes the internal baffle-to-baffle (B-B) bolts, external B-B bolts and the associated locking devices and locking welds, and the core barrel-to-former (CB-F) bolts and the associated locking devices and locking welds

Information considered by AREVA to be proprietary is marked with brackets: **[ ]**

2.0 BACKGROUND

The CBA is a flanged cylinder, with its top flange bolted to the bottom flange of the core support shield assembly and its bottom flange bolted to the top flange of the lower internals assembly [1]. The CBA consists of the flanged CB cylinder, baffle plates, former plates, thermal shield, and the associated bolting, as shown in Figure 2-1, Figure 2-2, and Figure 2-3. Its functions are to direct the flow of coolant and to support the lower internals assembly. In addition, the thermal shield reduces the amount of radiation that reaches the reactor vessel.

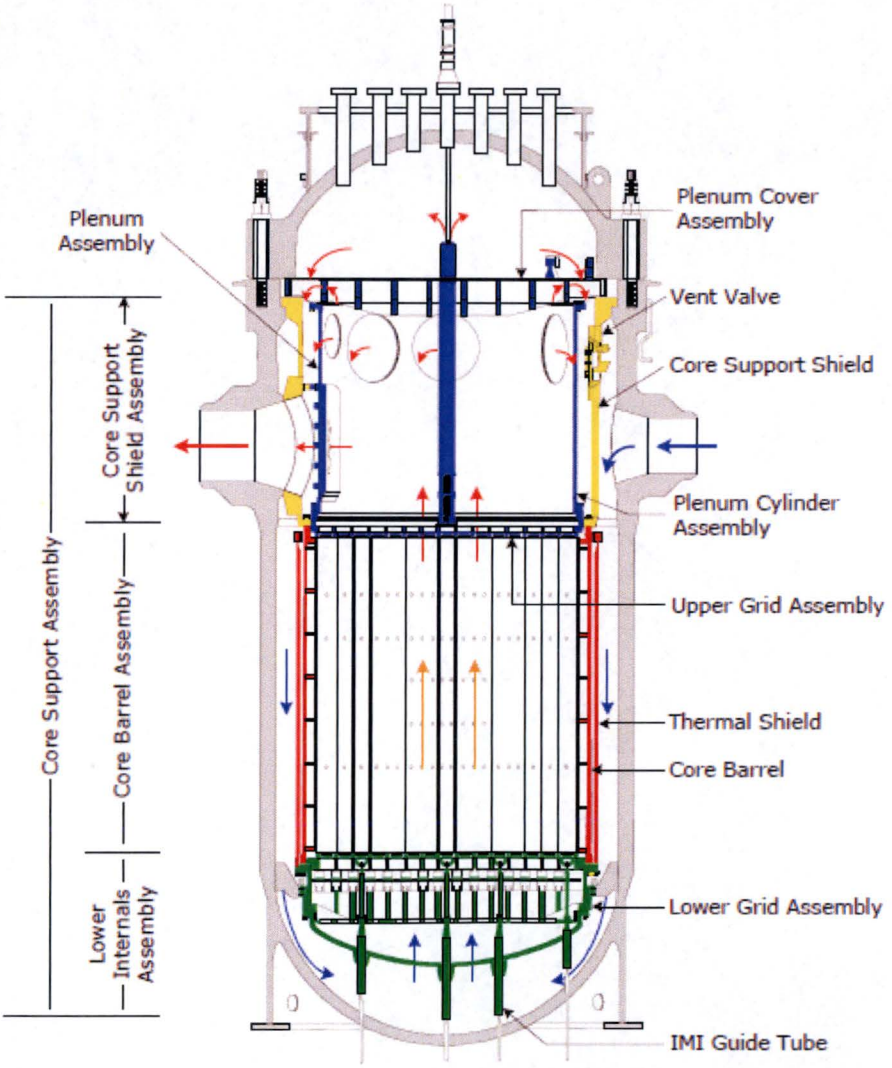

Figure 2-1: Overview of Typical Babcock &Wilcox Reactor Vessel Internals [1]

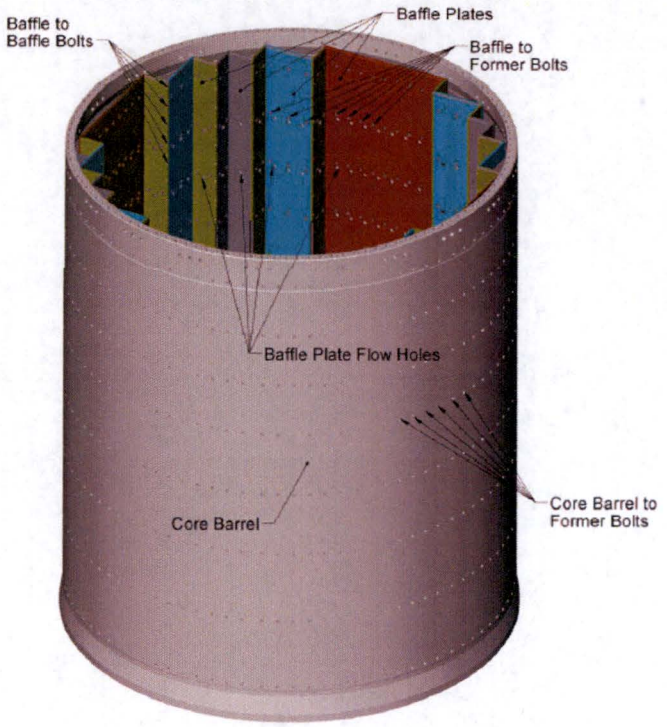

Figure 2-2: Core Barrel Assembly (Thermal Shield not Shown)

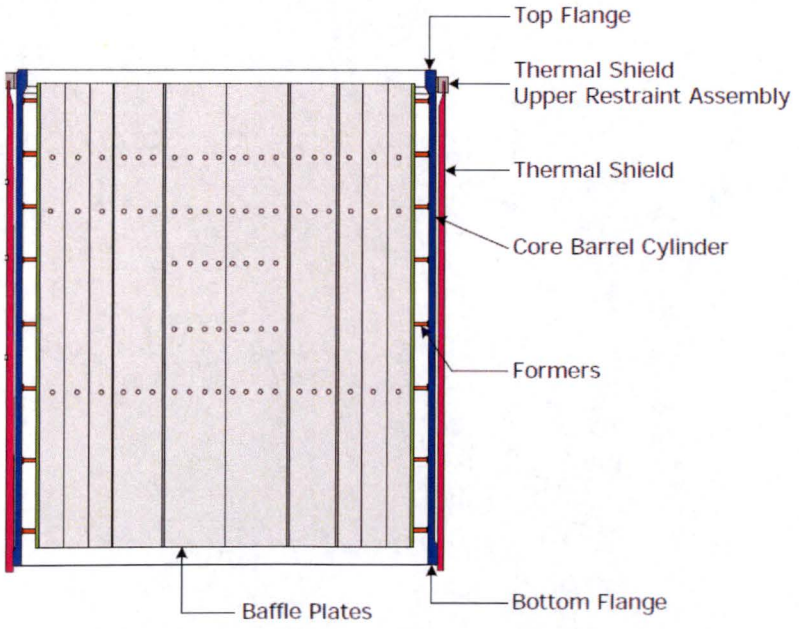

Figure 2-3: Core Barrel Assembly (Cross-Section)

The MRP-227-A A/LAI 6 applicable component items (as listed in Section 1.0) are shown in Table 2-1 along with the primary item-to-expansion item linkage [1]. Unless otherwise noted, the expansion component items have the same age-related degradation mechanisms as the linked primary component items.

Based on the results of the MRP-227-A inspections at the three ONS units, no relevant indications were reported for the primary component items listed in Table 2-1, with the exception of a reportable indication in one B-F bolt.

Table 2-1 MRP-227-A A/LAI 6 Applicable Component Items and Welds Primary-to-Expansion Linkage

Primary Component Item(s)	Age-Related Degradation Mechanism(s)	Expansion Component Item(s)
Baffle-to-Former Bolts	Irradiation-Assisted Stress Corrosion Cracking (IASCC), Irradiation Embrittlement (IE), and Irradiation-Enhanced Stress Relaxation/Irradiation Creep (ISR/IC)	External Baffle-to-Baffle Bolts and Core Barrel-to-Former Bolts
	IE, Overload, and ISR/IC	Internal Baffle-to-Baffle Bolts
Baffle Plates	IE	Core Barrel Cylinder (including vertical and circumferential seam welds) Former Plates
Locking Devices (including locking welds) of Baffle-to-Former Bolts and Internal Baffle-to-Baffle Bolts	IASCC, IE, Overload[1]	Locking Devices (including locking welds) of Core Barrel-to-Former Bolts and External Baffle-to-Baffle Bolts

[1] The expansion component items and welds are not linked to overload failure, but only IASCC and IE.

3.0 OVERALL METHODOLOGY

The following is the overall methodology for addressing A/LAI 6:

- First, justify that the CB cylinder (which includes vertical and circumferential seam welds) is unlikely to fail during the period of extended operation, and, thus is expected to maintain functionality (detailed methodology in Section 4.2)

- Second, justify that the former plates are unlikely to fail during the period of extended operation, and thus, are expected to maintain functionality (detailed methodology in Section 5.2)

- Third, justify that sufficient failures of applicable CBA bolting (i.e., internal B-B bolts, external B-B bolts and their associated locking devices and locking welds, and CB-F bolts and their associated locking devices and locking welds) to affect CBA functionality are unlikely to occur during the period of extended operation (detailed methodology in Section 6.2)

- Lastly, use the above information to address potential interdependence between the inaccessible or non-inspectable component items during the period of extended operation

4.0 CORE BARREL CYLINDER EVALUATION

This section will justify that the CB cylinder (which includes vertical and circumferential seam welds) is unlikely to fail[2] during the period of extended operation and, thus, is expected to maintain functionality. The functions of the CB cylinder are to 1) direct flow down through the annulus between the CB cylinder and the reactor vessel, 2) support the former plates and baffle plates, 3) support the lower internals, and 4) support the thermal shield. These functions support the function of the CBA (i.e., direct the flow of coolant and to support the lower internals assembly).

4.1 *Background*

Per the results of the MRP-227-A process [1], the CB cylinder is susceptible to irradiation embrittlement (IE), which is the phenomenon of reduction in ductility and fracture toughness from exposure to high energy neutrons (E > 1.0 Mega electron Volts [MeV]). This decrease in ductility is accompanied by an increase in yield strength. The resultant effects on mechanical properties are due to (in part) point defects created in the atomic lattice from the neutron bombardment, which impede or hinder plastic deformation.

4.2 *Detailed Methodology*

The following methodology was used to address A/LAI 6 for the CB cylinder:

- First, discuss the factors affecting susceptibility to failure as the result of reduced fracture toughness from IE (Section 4.3.1)

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[2] Failure of the core barrel cylinder herein refers to [

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- Lastly, use the results of the above steps to justify that failure of the CB cylinder is unlikely during the period of extended operation and, thus, the CB cylinder is expected to maintain functionality (Section 4.4)

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4.3 *Evaluation*

This section will implement the methodology stated above.

4.3.1 Factors Affecting Susceptibility to Failure by Irradiation Embrittlment

Failure related to IE is defined as rapid unstable crack growth (i.e., fast fracture) due to the effects of IE and high tensile stresses. This can be caused by two scenarios 1) overload from an applied tensile stress greater than the yield strength or 2) the existence of a flaw with an applied stress, potentially significantly lower than the yield strength, which exceeds the reduced fracture toughness of the material. [

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4.4 *Conclusion*

Per the MRP-227-A process, the CB cylinder (which includes the vertical and circumferential seam welds) is susceptible to a reduction in toughness due to IE. Failure related to IE is rapid unstable crack growth (i.e., fast fracture), [

] Therefore, the ONS CB cylinder is unlikely to fail due to the effects of IE during the period of extended operation and, thus, the CB cylinder is expected to maintain functionality.

5.0 FORMER PLATE EVALUATION

This section will justify that the former plates are unlikely to fail[3] during the period of extended operation and, thus, are expected to maintain functionality. The functions of the former plates are to 1) support the baffle plates (in conjunction with the B-F and CB-F bolts) and 2) to allow flow through the annulus between the baffle plates and CB cylinder (through flow holes in the former plates). Both of these functions contribute to the "direct the flow of coolant" portion of the function of the CBA.

5.1 *Background*

Per the results of the MRP-227-A process [1], the former plates are susceptible to IE, which is the phenomenon of reduction in ductility and fracture toughness from exposure to high energy neutrons (E > 1.0 MeV). This decrease in ductility is accompanied by an increase in yield strength.

5.2 *Detailed Methodology*

The following methodology was used to address A/LAI 6 for the former plates:

- First, discuss the factors affecting susceptibility to failure as the result of reduced fracture toughness from IE (Section 5.3.1)

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[3] Failure of the former plates herein refers to [

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- Lastly, use the results of the above steps to justify that failure of the former plates is unlikely during the period of extended operation and, thus, the former plates are expected to maintain functionality (Section 5.4)

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5.3 *Evaluation*

This section will implement the methodology stated above.

5.3.1 Factors Affecting Susceptibility to Failure by Irradiation Embrittlement

The discussion provided in Section 4.3.1 is also applicable here to the former plates.

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5.3.5 [ ]

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5.3.6 [ ]

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5.3.7 [ ]

Service-induced flaws include fatigue, SCC, and IASCC. Per the MRP-227-A process [1], the former plates were screened as not susceptible to fatigue, SCC, and IASCC (i.e., these degradation mechanisms were categorized as Category A or "no additional measures"). Therefore, service-induced flaws in the ONS former plates are not a concern during the period of extended operation.

5.4 *Conclusion*

Per the MRP-227-A process, the former plates are susceptible to a reduction in toughness due to IE. Failure related to IE is rapid unstable crack growth (i.e., fast fracture), [

] Therefore, the ONS former plates are unlikely to fail due to the effects of IE during the period of extended operation and, thus, the former plates are expected to maintain functionality.

6.0 APPLICABLE CORE BARREL ASSEMBLY BOLTING EVALUATION

This section will justify that sufficient failures[4] of applicable CBA bolting (i.e., internal B-B bolts, external B-B bolts and the associated locking devices and locking welds, and the CB-F bolts and the associated locking devices and locking welds) to affect CBA functionality is unlikely to occur during the period of extended operation. Note that the applicable CBA bolting does not have any safety function beyond supporting the [ ] function of the CBA. The specific function of each applicable CBA bolting item is discussed below for reference.

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6.1 *Background*

Per the MRP-227-A process [1], the applicable CBA bolting is susceptible to the following degradation mechanisms: IASCC, IE, overload (due to void swelling [VS] of the baffle plates), and ISR/IC, as shown in Table 6-1. The age-related degradation mechanisms applicable to these component items and welds are also applicable to the B-F bolts and their locking devices and welds and internal B-B bolt locking devices and welds, which are inspectable and serve as the linked primary component items for these uninspectable component items and welds.

[4] Failure of an inaccessible or non-inspectable bolt is defined as the bolt no longer performing its function due to one or more of the applicable age-related degradation mechanisms. The definition of failure is the same for the locking devices and welds.

Table 6-1 Applicable Age-Related Degradation Mechanisms of ONS Core Barrel Assembly Bolting and Locking Devices/Welds

Component	Applicable Age-Related Degradation Mechanism			
	IASCC	ISR/IC Leading to Wear and Fatigue	IE	Void Swelling of Baffle Plate Leading to Bolt Overload
Bolts				
B-F Bolts (Note 1)	X	X	X	X
CB-F Bolts	X	X	X	
Internal B-B Bolts		X	X	X
External B-B Bolts	X	X	X	
Locking Devices and Locking Welds				
B-F Bolt Locking Devices and Locking Welds (Note 1)	X		X	
CB-F Bolt Locking Devices and Locking Welds	X		X	
Internal B-B Bolt Locking Devices and Locking Welds (Note 1)	X		X	
External B-B Bolt Locking Devices and Locking Welds	X		X	

Note 1: These component items and welds are outside the scope of A/LAI 6, [

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6.2 *Detailed Methodology*

The following methodology was used to address A/LAI 6 for the applicable CBA bolting:

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- Lastly, use the above to justify that sufficient failures of the applicable CBA bolting to affect the functionality of the CBA is not expected to occur during the period of extended operation

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6.3 *Evaluation*

This section will implement the methodology stated above.

6.3.1 Failure of the Locking Devices and Locking Welds of the External B-B Bolts and CB-F Bolts

The locking devices and the locking welds for the internal B-B bolts and the B-F bolts (primary component items) are leading indicators for age-related degradation for the locking devices and the locking welds for the external B-B bolts and CB-F bolts (linked expansion component items). These primary component items are leading indicators for the expansion component items because they are susceptible to overload (due to slip between the baffle plates and bolts) in addition to IASCC and IE, as noted in Table 2-1. The primary component items (locking devices and the locking welds for the internal B-B bolts and the B-F bolts) were recently inspected using VT-3 visual techniques at all three ONS units with no indication of age-related degradation. [

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6.3.2 IASCC of the B-B and CB-F Bolts

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6.3.3 Irradiation Embrittlement

Failure of the CB-F and B-B bolts due to the reduction in toughness from IE requires the presence of a flaw. This is conservatively addressed by the IASCC evaluation herein,

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6.3.4 Irradiation-Enhanced Stress Relaxation/Irradiation Creep Effects on Susceptibility to Wear and Fatigue

ISR/IC of the CB-F and B-B bolts results in a reduction in preload, which could increase susceptibility to wear and/or fatigue. [

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6.3.5 Void Swelling of Baffle Plates Effects on Bolting

The consequence of void swelling of the baffle plate on inaccessible and non-inspectable bolts [

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6.3.6 Summary and Results

Of the age-related degradation mechanisms applicable to the inaccessible and non-inspectable bolting components items, [

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[

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[

] The results indicate that the functionality of the CBA is justified through the period of extended operation.

Figure 6-1: [ ]

6.4 *Conclusion*

Of the age-related degradation mechanisms applicable to the inaccessible and non-inspectable bolting component items, [

] Given the operating experience at ONS to date and the results of the evaluation discussed above, sufficient failures of the applicable CBA bolting to affect CBA functionality is unlikely to occur during the period of extended operation.

7.0 INTERDEPENDENCE OF INACCESSIBLE OR NON-INSPECTABLE COMPONENT ITEMS

The CB cylinder, former plates, and applicable CBA bolting are not accessible for inspection. [

] Therefore, interdependence is not a concern at this time.

8.0 OVERALL CONCLUSIONS

This report summarized the analyses performed for the applicable component items at ONS to complete A/LAI 6 from MRP-227-A. The following conclusions were reached:

- The CB cylinder is unlikely to fail during the period of extended operation and, therefore, is expected to maintain functionality
- The former plates are unlikely to fail during the period of extended operation and, therefore, are expected to maintain functionality
- Sufficient failures of applicable CBA bolting (i.e., internal B-B bolts, external B-B bolts and the associated locking devices and locking welds, and the CB-F bolts and the associated locking devices and locking welds) to affect CBA functionality is unlikely to occur during the period of extended operation and, therefore, the CBA is expected to maintain functionality

9.0 REFERENCES

1 Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines (MRP-227-A). EPRI, Palo Alto, CA: 2011. 1022863.

2 Attachment to AREVA letter from T. Natour to J. Molkenthin, AREVA-13-02949, "AREVA Revised Text for Draft WCAP-17096-NP Revision 2 for Transmittal to EPRI to Address NRC Reviewer Comments," October 23, 2013, NRC Accession Number ML16043A095.

3 "Reactor Internals Acceptance Criteria Methodology and Data Requirements," WCAP-17096-NP, Revision 2, December 2009, NRC Accession Number ML101460157.

4 Materials Reliability Program: PWR Internals Age-Related Material Properties, Degradation Mechanisms, Models, and Basis Data—State of Knowledge (MRP-211). EPRI, Palo Alto, CA: 2007. 1015013.