babcock & wilcox nuclear energy

B&W mPower™ Reactor Fuel System Mechanical Design Criteria MPWR-TECR-005012 Revision 000 9/23/2011

(REDACTED VERSION)

a progressive energy solution

B&W mPower™ Reactor Program
Babcock & Wilcox Nuclear Energy, Inc.
109 Ramsey Place
Lynchburg, VA 24501

Babcock & Wilcox Nuclear Energy, Inc.
a Babcock & Wilcox company
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SIGNATURES			
Prepared By:	E. A. Barringer		9/23/11
	Name	Signature	Date
Reviewed By:	T.L. Lotz		9/23/2011
	Name	Signature	Date
Reviewed By:	J.K. Witter		9/23/2011
	Name	Signature	Date
Reviewed By:	C. Poslusny		9/26/2011
	Name	Signature	Date
Approved By:	V.J. Bilovsky		9/26/2011
	Name	Signature	Date

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1. INTRODUCTION

The purpose of this technical report is to provide a description of the Babcock & Wilcox (B&W) mPower™ fuel system design, including key design parameters and illustrations, and to present a compilation of the fuel system design bases and criteria. A Fuel System Mechanical Design Topical report, based on the design bases and criteria contained herein, will be submitted to the NRC upon completion of the detailed analyses and testing.

Section 2 of this report describes the design of the B&W mPower fuel assembly and in-core control components. The information provided in this report represents the current design; it is expected that minor changes to the design will occur during the next two years through the fuel system development and licensing process.

Section 3 describes the fuel system mechanical design bases and criteria, with a general discussion of the approach to evaluating the design relative to the criteria.

2. FUEL SYSTEM DESIGN SUMMARY

The B&W mPower fuel assembly has been designed specifically for use with the core configuration of the B&W mPower reactor. The key fuel assembly parameters are listed in Table 2.0-1. Figure 2.0-1 shows a cross-section of the fuel assembly array, and Figure 2.0-2 provides a fuel assembly full-length view.

The 17x17 fuel assembly consists of [

] [CCI per Affidavit 4(a)-(d)]

2.1 Fuel Rods

[

] **[CCI per Affidavit 4(a)-(d)]**

2.2 Burnable Poison Rods

Supplementary reactivity control is provided by non-integral burnable poison rods (BPRs). [

] **[CCI per Affidavit 4(a)-(d)]**

2.3 Fuel Assembly Structure

The fuel assembly structural skeleton consists of the upper end fitting and the cage assembly. The fuel assembly cage, shown in Figure 2.3-1, includes the lower end fitting, the control rod guide tubes, and the spacer grids.

2.3.1 Lower End Fitting

A schematic view of the lower end fitting is provided in Figure 2.3.1-1. [

] **[CCI per Affidavit 4(a)-(d)]**

2.3.2 Upper End Fitting

The upper end fitting is the uppermost structural component of the fuel assembly. [

] **[CCI per Affidavit 4(a)-(d)]**

2.3.3 Control Rod Guide Tube Assembly

[

] **[CCI per Affidavit 4(a)-(d)**

2.3.4 Grid Assemblies

[

] **[CCI per Affidavit 4(a)-(d)]**

2.4 <u>In-core Control Components</u>

[

] **[CCI per Affidavit 4(a)-(d)]**

2.4.1 Control Rod Assemblies

[

] **[CCI per Affidavit 4(a)-(d)]**

2.4.2 Neutron Source Rods

[

] [CCI per Affidavit 4(a)-(d)]

Table 2.0-1 B&W mPower Fuel Assembly Design Summary

[

]

[CCI per Affidavit 4(a)-(d)]

Table 2.0-1 B&W mPower Fuel Assembly Design Summary (continued)

[

]

[CCI per Affidavit 4(a)-(d)]

Table 2.4.1-1 B&W mPower Control Rod Assembly Design Summary

[

[CCI per Affidavit 4(a)-(d)]

Table 2.4.2-1 B&W mPower Neutron Source Rod Design Summary

[

]

[CCI per Affidavit 4(a)-(d)]

[

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[CCI per Affidavit 4(a)-(d)]

Figure 2.0-1 Fuel Assembly Cross-Section

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.0-2 Fuel Assembly Full-Length View

[ ]

[CCI per Affidavit 4(a)-(d)]

Figure 2.0-3 Fuel Assembly Interface with Reactor Upper Internals

[CCI per Affidavit 4(a)-(d)]

Figure 2.1-1 Fuel Rod Schematic

[

]

[CCI per Affidavit 4(a)-4(d)]

Figure 2.2-1 Burnable Poison Rod

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3-1 Cage Assembly

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.1-1 Lower End Fitting

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.1-2 Control Rod Guide Tube Assembly to LEF Joint

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.2-1 Upper End Fitting

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.2-2 Control Rod Guide Tube Assembly to UEF Joint

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.3-1 Control Rod Guide Tube Assembly

[ ]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.3-2 Constraint Design for End Grids on Control Rod Guide Tubes

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.3-3 Constraint Design for Mid Grids on Control Rod Guide Tubes

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.4-1 End Grid

[ ]

[CCI per Affidavit 4(a)-(d)]

Figure 2.3.4-2 Intermediate Spacer Grid

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.4.1-1 Type 1 Control Rod Assembly

[ ]

[CCI per Affidavit 4(a)-(d)]

Figure 2.4.1-2 Control Rod

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.4.1-3 Spider Assembly

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.4.1-4 Type 2 Control Rod Assembly

[ ]

[CCI per Affidavit 4(a)-(d)]

Figure 2.4.1-5 Hybrid Control Rod

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.4.2-1 Primary Neutron Source Rod

[

]

[CCI per Affidavit 4(a)-(d)]

Figure 2.4.2-2 Secondary Neutron Source Rod

3. FUEL SYSTEM DESIGN BASES AND CRITERIA

3.1 Fuel System Design Bases Summary

3.1.1 Design Requirements

Design requirements for the fuel system are described in the NRC Standard Review Plan (SRP) 4.2 (NUREG-0800) (Reference 4.1). These requirements are in compliance with General Design Criteria (GDC) 10, 27 and 35 of 10 CFR Part 50 Appendix A (Reference 4.2), 10 CFR Part 50.46 (Reference 4.3) and 10 CFR Part 100 (Reference 4.4). The requirements are also consistent with Section 4.2 of Regulatory Guide 1.70 (Reference 4.5) and with Section C.I.4.2 of Regulatory Guide 1.206 (Reference 4.6).

The design basis objectives of the fuel system are to ensure that:

(a) the fuel system is not damaged as a result of normal operation or anticipated operational occurrences (AOOs);

(b) fuel system damage is never so severe as to prevent control rod insertion when it is required;

(c) the number of fuel rod failures is not underestimated for postulated accidents (PAs); and

(d) core coolability is always maintained.

GDC 10 (Reactor design), within Appendix A to 10 CFR Part 50, addresses item (a) above: "The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margins to ensure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences." Specifically, GDC 10 establishes Specified Acceptable Fuel Design Limits (SAFDLs) to ensure that the fuel system is not damaged.

With respect to the fuel system design, "not damaged" means that fuel rods do not fail, that the fuel system remains within operational tolerances, and that the functional capabilities are not reduced below those assumed in the safety analysis.

"Fuel rod failure" means that the fuel rod leaks and that the first fission product barrier (the cladding) has been breached. This criterion relates to 10 CFR Part 100, dose analysis.

"Coolability" means that the fuel assembly retains its rod-bundle geometry with adequate coolant flow passages (channels) to permit removal of residual heat even after a severe accident.

General requirements to maintain control rod insertability and core coolability appear repeatedly in GDC 27 (Combined reactivity control systems capability) and GDC 35 (Emergency core cooling). Specific coolability requirements for the loss-of-coolant accident (LOCA) are provided in 10 CFR Part 50.46.

To address these requirements, design criteria for the fuel system are categorized with respect to:

(A) fuel system damage

(B) fuel rod and burnable poison rod failure

(C) fuel coolability

The complete set of design criteria required in SRP 4.2 (Reference 4.1) are listed in Table 3.1.1-1 to Table 3.1.1-3. Criteria related to fuel system damage and their applicability to fuel system components are summarized in Table 3.1.1-1. Criteria related to the failure of fuel rods and burnable poison rods are summarized in Table 3.1.1-2. Criteria related for fuel coolability and their applicability to fuel system components are summarized in Table 3.1.1-3.

Section 3.2 of this report presents a review of the B&W mPower fuel rod and fuel assembly design bases and criteria. It is noted that for some requirements related to postulated accidents, the Design Control Document (DCD) is referenced for the detailed discussion of the requirement.

3.1.2 Plant Conditions for Fuel System Design

Plant conditions for fuel assembly design are categorized according to expected frequency of occurrence and by type, as follows:

(1) Normal operation (NO)

(2) Anticipated Operational Occurrences (AOOs)

(3) Postulated Accidents (PAs)

Normal operation typically includes the following events that are expected frequently or are performed regularly in the course of power operation, refueling, maintenance, and maneuvering of the plant (Reference 4.7):

Startup
Shutdown (hot and cold)
Refueling
Hot standby
Power operation
Operational maneuvers
Plant heatup and cooldown

Load change

Operation with permissible deviations

Anticipated operational occurrences, as defined in 10 CFR Part 50, Appendix A, are those conditions of operation that are expected to occur one or more times during the life of the nuclear plant. Postulated accidents are unanticipated occurrences. That is, they are postulated but are not expected to occur during the life of the nuclear power plant.

Analyses of AOOs and PAs are categorized according to type so that analysts can compare them on common bases, effect, and safety limits. Such comparisons can help to identify limiting event and cases for detailed examination, and eliminate non-limiting cases from further consideration.

AOOs and PAs are grouped into the following seven types (Reference 4.7):

(1) Increase in heat removal by the secondary system
(2) Decrease in heat removal by the secondary system
(3) Decrease in reactor cooling system (RCS) flow rate
(4) Reactivity and power distribution anomalies
(5) Increase in reactor coolant inventory
(6) Decrease in reactor coolant inventory
(7) Radioactive release from a component or subsystem

The events for AOOs and PAs for the B&W mPower plant will be categorized in Chapter 15 (Transient and Accident Analysis) of the DCD to specify the limiting event for fuel system integrity.

Table 3.1.1-1 Criteria for Fuel System Damage

SRP Acceptance Criteria for (A) Fuel System Damage										Related Chapter/Section to be Reviewed in DCD
1.A.i	Cladding Stress									Section 4.2 (Fuel System Design)
	Cladding Strain									Section 4.2 (Fuel System Design)
	Loading Limits									Section 4.2 (Fuel System Design)
1.A.ii	Cladding and Component Fatigue									Section 4.2 (Fuel System Design)
1.A.iii	Fretting Wear									Section 4.2 (Fuel System Design)
1.A.iv	Cladding and Component Oxidation, Hydriding, CRUD									Section 4.2 (Fuel System Design) Effects of CRUD discussed in Sections 4.3 and 4.4
1.A.v	Dimensional Changes									Section 4.2 (Fuel System Design)
1.A.vi	Rod Internal Pressure (no cladding liftoff, no hydride reorientation)									Section 4.2 (Fuel System Design)
	Rod Internal Pressure (DNB propagation)									Section 4.2 (Fuel System Design)
1.A.vii	Assembly Liftoff									Section 4.2 (Fuel System Design) and Hydraulic load evaluation discussed in Section 4.4
1.A.viii	Control Rod Reactivity Insertability									Section 4.2 (Fuel System Design)

[CCI per Affidavit 4(a)-(d)]

Table 3.1.1-2 Criteria for Fuel Rod and Burnable Poison Rod Failure

SRP Acceptance Criteria for (B) Fuel Rod Failure										Related Chapter/Section to be Reviewed in DCD
1.B.i	Hydriding (Internal)									Section 4.2 (Fuel System Design)
	Hydriding (External from corrosion)									Section 4.2 (Fuel System Design)
1.B.ii	Cladding Collapse									Section 4.2 (Fuel System Design)
1.B.iii	Overheating of Cladding									Section 4.2 (Fuel System Design) Section 4.4 (Thermal and Hydraulic Design)
1.B.iv	Overheating of Fuel Pellet									Section 4.2 (Fuel System Design) Chapter 15 (Transient and Accident Analysis)
1.B.v	Excessive Fuel Enthalpy									Chapter 15 (Transient and Accident Analysis)
1.B.vi	Pellet-Clad Interaction (PCI and PCMI)									Section 4.2 (Fuel System Design)
1.B.vii	Bursting									Chapter 15 (Transient and Accident Analysis)
1.B.viii	Mechanical Fracture									Section 4.2 (Fuel System Design)

[CCI per Affidavit 4(a)-(d)]

Table 3.1.1-3 Criteria for Fuel Coolability

SRP Acceptance Criteria for (C) Fuel Coolability [										Related Chapter/Section to be Reviewed in DCD
1.C.i	Cladding Embrittlement (PCT <2200°F, oxidation <17% ECR)									Chapter 15 (Transient and Accident Analysis)
1.C.ii	Violent Expulsion of Fuel (Criteria in SRP 4.2, Appendix B)									Chapter 15 (Transient and Accident Analysis)
1.C.iii	Generalized Cladding Melting									Chapter 15 (Transient and Accident Analysis)
1.C.iv	Fuel Rod Ballooning (Methods in RG 1.157)									Chapter 15 (Transient and Accident Analysis)
1.C.v	Structural Deformation (Criteria in SRP 4.2, Appendix A)								]	Chapter 15 (Transient and Accident Analysis)

[

]

[CCI per Affidavit 4(a)-(d)]

3.2 Design Criteria and Methodology for Evaluating Fuel System Damage

Fuel system damage requirements apply to normal operation and AOOs. To meet the requirements of GDC 10 as it relates to SAFDLs for normal operation, including AOOs, fuel system damage criteria are specified for all known damage mechanisms.

Fuel damage criteria ensure that fuel system dimensions remain within operational tolerances and that functional capabilities are not reduced below those assumed in the safety analysis. When applicable, the fuel damage criteria consider high burnup effects based on irradiated material properties.

3.2.1 Cladding Stress

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.2 Cladding Strain

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[ ] **[CCI per Affidavit 4(a)-(d)]**

3.2.3 Stress and Loading Limit for Other than Cladding

3.2.3.1 Loads Applied by Core Restraint System

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

The design criteria associated with loads applied by the core restraint system are:

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.3.2 Loads Applied in Fuel Handling and Shipping

(1) Design Basis

[ ]

[CCI per Affidavit 4(a)-(d)]

(2) Design Criteria

The design criteria associated with loads applied during shipping and handling are:

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.4 Cladding Fatigue

(1) Design Basis

[
] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.5 Fretting Wear

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.6 Cladding Oxidation and Hydriding (and CRUD Buildup)

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[ ] **[CCI per Affidavit 4(a)-(d)]**

3.2.7 Dimensional Change

3.2.7.1 Fuel Assembly Growth

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.7.2 Fuel Rod Axial Growth

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.7.3 Rod Bowing

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

]

[CCI per Affidavit 4(a)-(d)]

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.7.4 Dimensional Stability of Spacer Grids

(1) Design Basis

[To maintain sufficient restraint on the fuel rods and burnable poison rods during irradiation, and during loading and unloading operations for fuel assemblies, the spacer grids are designed to maintain dimensional stability during irradiation.] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

]

[CCI per Affidavit 4(a)-(d)]

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.8 Rod Internal Pressure

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.9 Assembly Liftoff

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.3 Design Criteria and Methodology for Evaluating Fuel Rod and BPR Failure

Fuel rod failure and burnable poison rod failure apply to normal operation, AOOs, and postulated accidents. Fuel rod and burnable poison rod failure is defined as the loss of rod hermeticity. [

] **[CCI per Affidavit 4(a)-(d)]**

The fuel rod and burnable poison rod failure criteria to be applied to the B&W mPower fuel system design are defined below.

3.3.1 Hydriding

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[ ] **[CCI per Affidavit 4(a)-(d)]**

3.3.2 Cladding Collapse

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[ ] **[CCI per Affidavit 4(a)-(d)]**

3.3.3 Overheating of Cladding

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[ ] **[CCI per Affidavit 4(a)-(d)]**

3.3.4 Overheating of Fuel Pellets (Melting)

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.3.5 Excessive Fuel Enthalpy

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

The detailed evaluation of this criterion is discussed in Chapter 15 (Transient and Accident Analysis) of the DCD. [

]

[CCI per Affidavit 4(a)-(d)]

3.3.6 Pellet-Cladding Interaction (PCI)

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

The methodology for the cladding strain evaluation is described in Section 3.2.2, and that for fuel pellet and burnable poison pellet centerline melting is described in Section 3.3.4.

3.3.7 Bursting

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[ ] **[CCI per Affidavit 4(a)-(d)]**

The details of this evaluation are discussed in Chapter 15 (Transient and Accident Analysis) of the DCD.

3.3.8 Fuel Rod Mechanical Fracturing

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

3.4 Design Criteria and Methodology for Evaluating Fuel Coolability

Coolability, or coolable geometry, implies that the fuel assembly retains its rod-bundle geometry with adequate coolant channels to permit removal of residual heat. Reduction of coolability can result from cladding embrittlement, violent expulsion of fuel, generalized cladding melting, gross structural deformation, and extreme coplanar fuel rod ballooning.

The fuel coolability criteria described below are applied to the analysis of postulated accidents. The details of the evaluations and analyses performed to assess these are presented in Chapter 15 (Transient and Accident Analysis) of the DCD.

3.4.1 Cladding Embrittlement

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ]

[CCI per Affidavit 4(a)-(d)]

(3) Design Evaluation

The detailed evaluation of the design criteria for cladding embrittlement is discussed in Chapter 15 (Transient and Accident Analysis) of the DCD.

3.4.2 Violent Expulsion of Fuel

(1) Design Basis

[ ] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[ ] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

The detailed evaluation is discussed in Chapter 15 (Transient and Accident Analysis) of the DCD.

3.4.3 Generalized Cladding Melting

[

] **[CCI per Affidavit 4(a)-(d)]**

3.4.4 Fuel Rod Cladding Ballooning

(1) Design Basis

[The fuel assemblies are designed such that fuel rod and burnable poison rod cladding ballooning does not preclude core coolability under postulated accident conditions.] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

In Chapter 15 (Transient and Accident Analysis) of the DCD, burst strain and flow blockage of Zircaloy-4 cladding are properly taken into account in the LOCA evaluation.

The possibility of DNB propagation is assessed in the non-LOCA evaluation.

3.4.5 Structural Deformation

(1) Design Basis

[

] **[CCI per Affidavit 4(a)-(d)]**

(2) Design Criteria

Under combined SSE and LOCA event loads:

[

] **[CCI per Affidavit 4(a)-(d)]**

(3) Design Evaluation

[

] **[CCI per Affidavit 4(a)-(d)]**

4. References

4.1	U.S. Nuclear Regulatory Commission, Standard Review Plan (NUREG-0800) Section 4.2, Revision 3, March 2007.
4.2	10 Code of Federal Regulation, Part 50 Appendix A

4.3	10 Code of Federal Regulation, Part 50.46
4.4	10 Code of Federal Regulation, Part 100
4.5	U.S Nuclear Regulatory Commission, Regulatory Guide 1.70, Section 4.2.
4.6	U.S. Nuclear Regulatory Commission, Regulatory Guide 1.206
4.7	ANSI/ANS-57.5-1996, "Light Water Reactors Fuel Assembly Mechanical Design and Evaluation," 1996.
4.8	ASME Boiler and Pressure Vessel Code, Section III, Subsection NG (2007 Edition with 2008 Addenda).
4.9	B. Watkins and D.S. Wood, "The Significance of Irradiation-Induced Creep on Reactor Performance of Zircaloy-2 Pressure Tube Applications - Related Phenomena for Zirconium and its Alloys," ASTM STP 458, American Society for Testing and Materials, pp. 226-240, 1969.
4.10	D.S. Wood and B. Watkins, "A Creep Limit Approach to the Design of Zircaloy-2 Reactor Pressure Tubes at 275 C," Journal of Nuclear Materials, 41, 327-340, May 1971.
4.11	Falcon Fuel Rod Performance Code Version 1.0, copyright 2010, Electric Power Research Institute, Inc.
4.12	American Standards and Test Methods (ASTM) C776-06, "Standard Specification for Sintered Uranium Dioxide Pellets".