Global Nuclear Fuel

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GE14 Thermal Hydraulic Compatibility With Grand Gulf Legacy Fuel

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1.0 Introduction

The thermal hydraulic compatibility report provides a summary of the thermal hydraulic evaluations performed to demonstrate acceptable thermal hydraulic compatibility of the GE14 fuel assembly with the Grand Gulf legacy fuel assemblies. The specific acceptance criterion associated with the thermal hydraulic compatibility of GE14 fuel with legacy fuel is that the new fuel is not to significantly degrade the performance of the legacy fuel in the core from a thermal hydraulic perspective. Specifically, during a transition to GNF GE14 fuel the legacy fuel should not experience unacceptable changes to MCPR, plenum-to-plenum pressure drop, or bundle flow. In addition, the introduction of GE14 fuel should not cause significant voiding in the bypass region or water rods. These characteristics will be addressed in the thermal hydraulic compatibility report.

Analyses cover the transition from a core loaded completely with Atrium™ – 10 fuel to one loaded completely with GE14 fuel. Steady state calculations are performed over a range of operating core flows and core thermal powers. The results of these evaluations support the conclusion that GE14 fuel and the legacy fuel can be safely and acceptably operated together at the Grand Gulf plant.

2.0 Calculation Process

2.1. Methods and Correlations

The ISCOR engineering computer program was used for all analyses documented in this report. ISCOR performs a steady state thermal hydraulic analysis of a nuclear reactor core. ISCOR is the code that implements the NRC approved methodology for performing steady state thermal hydraulic evaluations as described in Reference 1. Inputs required for the code include reactor core power level and distribution, inlet flow conditions, reactor core operation pressure, and a hydraulic description of the reactor fuel bundles. The code calculates the core flow distribution and core pressure drop for a given inlet core flow. The code considers the pressure drop and flow in the reactor core only. Detailed modeling of the bypass region, leakage flow paths, and water rod hydraulics is included. Pressure drop correlations are applied to calculated contributions due to friction, local losses, elevation, and acceleration. Thermal performance calculations for GE14 fuel are carried out using the GEXL14 critical quality – boiling length correlation (Reference 2). Thermal performance calculations for Atrium™ – 10 fuel are carried out using the GEXL97 correlation (Reference 3) to determine relative thermal performance in the Grand Gulf Core.

2.2. Assumptions

[[ ]] characteristics were assumed for all predictions of thermal hydraulic performance. This is consistent with the GNF design and licensing evaluation procedures.

[[ ]] fuel geometry with [[ ]] was used for both Atrium™ – 10 and GE14 fuel types. Flow to the bypass region via the GE14 channel-to-lower tie plate finger spring leakage path used [[ ]] conditions. Both assumptions tend to reduce leakage flow to the bypass. The minimum bypass flow condition provides a conservative determination of maximum expected bypass voiding while not significantly affecting the relative sharing of flow between fuel bundle types or the relative comparison of other performance parameters.

2.3. Inputs

The GE14 fuel assembly (Reference 4) has a 10 x 10 rod array with 92 fuel rods, fourteen of which are part length, and two large central water rods. The fuel and water rods are spaced and supported by the upper and lower tie plates, with intermediate spacing provided by eight Zircaloy ferrule spacers. The fuel assembly fits into a channel box consisting of a Zircaloy shell fitted to the lower tie plate. The geometrical inputs used in the thermal hydraulic design analyses were derived from the mechanical configuration of the assembly. Pressure drop local loss coefficients and critical power correlation coefficients (Reference 2) were derived from test data.

The Atrium™ – 10 fuel assembly has a 10 x 10 rod array with 91 fuel rods and a central water channel. There are 83 full length fuel rods and 8 partial length fuel rods. The fuel rods attach to the lower tie plate and upper tie plate with intermediate spacing provided by eight Zircaloy-4 spacers. The Zircaloy channel box is attached to the lower tie plate. A handle assembly is part of the upper tie plate used for lifting the entire assembly. The geometrical inputs used in the thermal hydraulic design analyses were derived from the mechanical configuration of the assembly. Pressure drop local loss coefficients were derived from information provided by Entergy/Areva.

Analyses were performed for three power/flow state points along the boundary of the Grand Gulf operating domain (Reference 5). The power/flow state points are: rated power at maximum flow, rated power at minimum flow, and minimum pump speed at maximum power (~66%P/34%F).

3.0 Criteria

The thermal hydraulic design process is closely coupled with other evaluations performed to demonstrate compliance with safety and performance criteria, including core nuclear design and the thermal hydraulic critical power correlations for Atrium™ – 10 fuel. The results from the design analyses documented in this report provide confirmation of the thermal hydraulic performance characteristics applied in these other evaluations. The specific acceptance criterion associated with the thermal hydraulic compatibility of GE14 fuel with legacy fuel is:

> ***The new fuel is not to significantly degrade the performance of the legacy fuel in the core from a thermal hydraulic perspective.***

Specifically, during a transition to GE14 fuel the legacy fuel should not experience unacceptable changes to MCPR, plenum-to-plenum pressure drop, or bundle flow. In addition, results will be provided to demonstrate that the introduction of GE14 fuel will not cause or experience significant voiding in the bypass region, the Atrium™ – 10 fuel water channel, or the GE14 water rods, thereby maintaining compatibility with core monitoring instrumentation.

4.0 Results

Core performance predictions for the three core power/flow analysis conditions are provided in Tables 1 through 3. As the GE14 core fraction increases, the core plenum-to-plenum pressure drop [[ ]]. The overall core pressure drop change is [[ ]] or less for the three power/flow state points analyzed. A hot bundle Hot Channel Power Peaking Factor of [[ ]] was used for this analysis. The Atrium™ – 10 bundles receive [[ ]] active flow at the higher core flows, which results in a [[ ]] average void fraction over fuel length. The Hot Bundle Active Flow changes by [[ ]] or less between an all Atrium™ – 10 core and an all GE14 core. The pressure drop comparisons between Atrium™ – 10 and GE14 designs are shown in Tables 4 through 6. These results show that the change in total pressure drop acoss the core comparing an all Atrium™ – 10 core to an all GE14 core is less than [[ ]].

Table 7 provides predictions for both the Atrium™ – 10 and GE14 for the hot bundle MCPR. It is seen that there is no degradation in CPR for the legacy fuel as GE14 fuel is introduced into the core. The largest delta in MCPR, including off rated conditions, is less than [[ ]]. Table 8 shows the GE14 Hot Bundle Water Rod Flow for the three power/flow analysis conditions. These results show that the flow through the GE14 Hot Bundle Water Rod is not degraded by the presence of Atrium™ – 10 fuel.

The water rod exit quality is analyzed for the GE14 fuel. The potential for water rod voiding increases as the core flow decreases leading to reduced water rod flow and inlet subcooling. Table 9 provides the exit quality for the GE14 water rod for the various core loadings and power/flow analysis conditions (minus the all Atrium™ – 10 core). Minimum voiding is expected for the GE14 water rod for the minimum pump speed condition.

The potential for voiding in the bypass region was evaluated for several core compositions, including all Atrium^{TM} – 10 fuel core. The power/flow analysis conditions include rated power/ increased core flow and rated power/reduced core flow (100%P/105%F and 100%P/77.1%F). Table 10 shows the Void Fraction and Exit Quality at the Top LPRM for the bypass region of the Hot Bundle and the Core average. In order to minimize the uncertainty in monitoring four bundle cell axial power using the thermal Traversing In-core Probe (TIP) system in conjunction with Local Power Range Monitors (LPRMs), it is necessary to prevent peak local bypass voiding at the top LPRM axial position from exceeding a [[ ]] void figure of merit. Table 10 demonstrates that none of the Top LPRM Void Fractions exceed [[ ]].

The sensitivity to the power shape was studied by analyzing an outlet peaked power shape at the rated power/increased core flow analysis conditions (100%P/105%F). Tables 1-10 are the results from a Bottom Peaked power shape. Tables 11 and 12 are from the Outlet Peaked power shape. Table 11 provides the core performance values for comparison to Table 1, which contains the core performance values for the bottom peaked power shape. The Top LPRM Void Fraction and Exit Quality of the bypass region for the top peaked power shape are given in Table 12, and can be compared to Table 10. It is seen that the Top LPRM Void fractions are [[ ]] or less for all bundles and fuel type combinations.

5.0 References

1. General Electric Standard Application for Reactor Fuel (GESTAR II), NEDE-24011-P-A-16, October 2007.

2. GEXL14 Correlation for GE14 Fuel, NEDC-32851P-A, Rev. 4, September 2007.

3. GEXL97 Correlation Applicable To Atrium™ – 10 Fuel, NEDC-33383P, Rev. 1, June 2008.

4. GE14 Compliance With Amendment 22 of NEDE-24011-P-A (GESTAR II), NEDC-32868P, Rev. 2, September 2007.

5. Safety Analysis Report for Grand Gulf Nuclear Station Thermal Power Optimization, NEDC-33048P, Revision 2, October 2002.

Figure 1. Axial Power Shape Profiles

[[

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Table 1. Core Performance (100%P/105%F)

Core Composition		Core Quantities		Hot Bundle Active Flow (kLb/hr)	
Atrium™ - 10	GE14	Pressure Drop (psi)	Bypass Flow (% of Total)	Atrium™ - 10	GE14
800	0	[[			
600	200				
400	400				
200	600				
0	800				]]

Table 2. Core Performance (100%P/77.1%F)

Core Composition		Core Quantities		Hot Bundle Active Flow (kLb/hr)	
Atrium™ - 10	GE14	Pressure Drop (psi)	Bypass Flow (% of Total)	Atrium™ - 10	GE14
800	0	[[			
600	200				
400	400				
200	600				
0	800				]]

Table 3. Core Performance (66%P/34%F)

Core Composition		Core Quantities		Hot Bundle Active Flow (kLb/hr)	
Atrium™ - 10	GE14	Pressure Drop (psi)	Bypass Flow (% of Total)	Atrium™ - 10	GE14
800	0	[[			
600	200				
400	400				
200	600				
0	800				]]

Table 4. Pressure Drop Comparison Atrium™ – 10 vs. GE14 (100%P/105%F)

100% Power & 105% Flow	Heterogeneous Core 50% Atrium™ - 10 50% GE14		Homogeneous Core	
	Atrium™ - 10	GE14	Atrium™ - 10	GE14
Total Bundle Flow (kLb/hr)	[[			
Pressure Drop (psi)	[redacted]	[redacted]	[redacted]	[redacted]
total friction				
total elevation				
total acceleration				
local losses				
Total				]]

Table 5. Pressure Drop Comparison Atrium™ – 10 vs. GE14 (100%P/77.1%F)

100% Power & 77.1% Flow	Heterogeneous Core 50% Atrium™ - 10 50% GE14		Homogeneous Core	
	Atrium™ - 10	GE14	Atrium™ - 10	GE14
Total Bundle Flow (kLb/hr)	[[			
Pressure Drop (psi)	[redacted]	[redacted]	[redacted]	[redacted]
total friction				
total elevation				
total acceleration				
local losses				
Total				]]

Table 6. Pressure Drop Comparison Atrium™ – 10 vs. GE14 (66%P/34%F)

66% Power & 34% Flow	Heterogeneous Core 50% Atrium™ - 10 50% GE14		Homogeneous Core	
	Atrium™ - 10	GE14	Atrium™ - 10	GE14
Total Bundle Flow (kLb/hr)	[[			
Pressure Drop (psi)	[redacted]		[redacted]	
total friction				
total elevation				
total acceleration				
local losses				
Total				]]

Table 7. Hot Bundle MCPR

Core Composition		100% Power 105% Flow		100% Power 77.1% Flow		66% Power 34% Flow	
Atrium™ - 10	GE14	Atrium™ - 10	GE14	Atrium™ - 10	GE14	Atrium™ - 10	GE14
800	0	[[					
600	200						
400	400						
200	600						
0	800						]]

Table 8. GE14 Hot Bundle Water Rod Flow (kLb/hr)

Core Composition		100% Power 105% Flow	100% Power 77.1% Flow	66% Power 34% Flow
Atrium™ - 10	GE14	GE14	GE14	GE14
800	0	[[		
600	200			
400	400			
200	600			
0	800			]]

Table 9. GE14 Water Rod Exit Quality

Core Composition		Core Power (%)	Core Flow (%)	Core Inlet Enthalpy (BTU/Lb)	GE14 Hot Bundle Water Rod Exit Quality	GE14 Avg Bundle Water Rod Exit Quality
Atrium™ - 10	GE14					
800	0	N/A				
600	200	100 100 66	105 77.1 34	[[		
400	400	100 100 66	105 77.1 34			
200	600	100 100 66	105 77.1 34			
0	800	100 100 66	105 77.1 34			]]

Table 10. Top LPRM Bypass Flow Quality and Void Fraction for Hot Bundle and Core Average

Core Composition		100% Power & 105% Flow				100% Power & 77.1% Flow			
		Hot Bundle		Core Average		Hot Bundle		Core Average	
Atrium™ - 10	GE14	Exit Quality	Top LPRM Void Fraction	Exit Quality	Top LPRM Void Fraction	Exit Quality	Top LPRM Void Fraction	Exit Quality	Top LPRM Void Fraction
800	0	[[							
600	200								
400	400								
200	600								
0	800								]]

Table 11. Core Performance (100% P & 105.0% F) (Outlet Peaked Axial Power Shape)

Core Composition		Core Quantities		Hot Bundle Active Flow (kLb/hr)	
Atrium™ - 10	GE14	Pressure Drop (psi)	Bypass Flow (MLb/hr)	Atrium™ - 10	GE14
800	0	[[			
600	200				
400	400				
200	600				
0	800				]]

Table 12. Top LPRM Bypass Flow Quality and Void Fraction for Hot Bundle and Core Average (Outlet Peaked Axial Power Shape)

Core Composition		100% Power & 105% Flow				100% Power & 77.1% Flow			
		Hot Bundle		Core Average		Hot Bundle		Core Average	
Atrium™ - 10	GE14	Exit Quality	Top LPRM Void Fraction	Exit Quality	Top LPRM Void Fraction	Exit Quality	Top LPRM Void Fraction	Exit Quality	Top LPRM Void Fraction
800	0	[[							
600	200								
400	400								
200	600								
0	800								]]

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