WESTINGHOUSE
FUEL ASSEMBLY RECONSTITUTION EVALUATION METHODOLOGY FOR VOGTLE UNIT 1 CYCLE 5

March 1993

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ABSTRACT

This document provides the evaluation methodology that was used for Vogtle Unit 1 Cycle 5 to analyze fuel assembly reconstitution. This document complements the NRC approved "Westinghouse Reload Safety Evaluation Methodology" topical report, WCAP-9272-P-A, that focuses on the analytical and safety aspects of the reload design activity and is consistent with the methodology in WCAP-13060-P, "Westinghouse Fuel Assembly Reconstitution Evaluation Methodology," currently under NRC review.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

During the current Vogtle-1 refueling outage, one damaged fuel rod was identified in fuel assembly 5F22, scheduled to be reloaded into the Vogtle 1 Cycle 5 core. The affected assembly location and fuel rod are shown in Figures 1 and 2. The mechanical features of the Vogtle 1 fuel assemblies permit the replacement of the damaged fuel rods with filler rods. This report describes the methodology that was employed to evaluate all applicable design criteria associated with reconstitution in the Vogtle Unit 1 Cycle 5 core that used a solid filler rod in place of the damaged uranium fuel rod.

Based on evaluations of the safety aspects of reconstitution, performed by the functional disciplines (Mechanical, Thermal-Hydraulic, Fuel Rod Performance, Nuclear, LOCA and non-LOCA) using NRC-approved methodologies, it was demonstrated that the effects of fuel assembly reconstitution on the Vogtle Unit 1 Cycle 5 core performance are minimal. These evaluations/analyses were performed using the methodology described in this report for the reconstituted fuel assembly in the Vogtle Unit 1 Cycle 5 core. The Cycle 5 methodology is identical to that methodology described in WCAP 13060-P and complements the NRC-approved, "Reload Safety Evaluation Methodology," WCAP-9272-P-A.

Figure 1

Reconstituted Core Loading Pattern

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1					5B	6A	5A	5A	5A	6A	5B				
2			2	6B	7A	7A	7A	7B	7A	7A	7A	6B	2		
3		2	7A	7B	7A	3	7A	6A	7A	3	7A	7B	7A	2	
4		6B	7B	6A	6A	7A	6B	6A	6B	7A	6A	6A	7B	6B	
5	5B	7A	7A	6A	7B	6A	7B	6A	7B	6A	7B	6A	7A	7A	5B
6	6A	7A	3	7A	6A	6A	6A	7B	6A	6A	6A	7A	3	7A	6A
7	5A	7A	7A	6B	7B	6A	7B	6A	7B	6A	7B	6B	7A	7A	5A
90° 8	5A	7B	6A	6A	6A	7B	6A	3	6A	7B	6A	6A	6A	7B	5A
9	5A	7A	7A	6B	7B	6A	7B	6A	7B	6A	7B	6B	7A	7A	5A
10	6A	7A	3	7A	6A	6A	6A	7B	6A	6A	6A	7A	3	7A	6A
11	5B	7A	7A	6A	7B	6A	7B	6A	7B	6A	7B	6A	7A	7A	5B
12		6B	7B	6A	6A	7A	6B	6A	6B	7A	6A	6A	7B	6B	
13		2	7A	7B	7A	3	7A	6A	7A	3	7A	7B	7A	2	
14			2	6B	7A	7A	7A	7B	7A	7A	7A	6B	2		
15					5B	6A	5A	5A	5A	6A	5B				

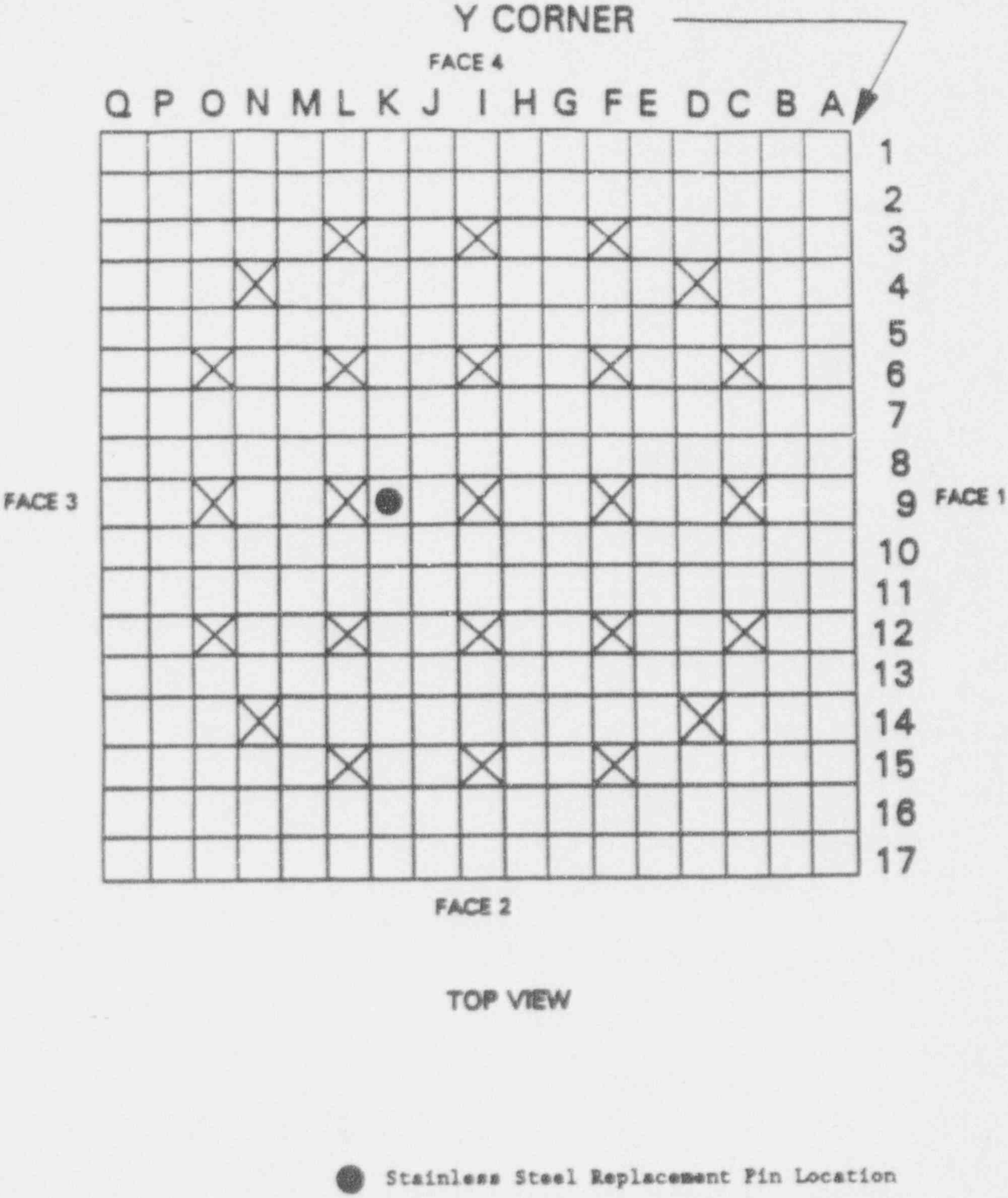
0°

LEGEND :

R — Region Identifier	2 — Location of Reconstituted Fuel Assembly (hatched)

Figure 2

Actual Location of Filler Rod Within Reconstituted Assembly 5F22



2.0 MECHANICAL DESIGN METHODOLOGY

2.1 Fuel Assembly Evaluation Methodology

The Vogtle Unit 1 Cycle 5 fuel assemblies are designed to perform satisfactorily under design loads throughout their lifetime. The loads, deflections and stresses resulting from the combined effects of normal operation and faulted condition loads were considered in the fuel assembly evaluation. The effect of replacement rods on the fuel assembly's mechanical properties and loads were assessed to insure that the reconstituted assembly met all the estabiished criteria. The introduction of the one replacement rod does not adversely impact the performance of the existing fuel assemblies.

All of the design criteria specified in Standard Review Plant (SRP) 4.2 (Reference 1) were reviewed. From a mechanical design and fuel coolability viewpoint, the mechanical criteria affected are the following:

- o Fuel Assembly Holddown Forces, and
- o Fuel Assembly Structural Response to Seismic/LOCA Loads.

The design basis for the fuel assembly holddown forces requires that the fuel assembly will not lift due to flow during normal operating conditions. The basis for the fuel assembly structural response to seismic/LOCA loads is the design requirements for combined seismic and LOCA loads per Appendix A to SRP 4.2.

The methodology used in the evaluation of these criteria and the results are further discussed in the following two sections.

2.2. Methodology Discussion

Fuel Assembly Holddown Force

The replacement rod shown in Figure 3 is a solid cylinder of stainless steel material. The replacement filler rod like a fuel rod is supported by the grid springs and dimples to maintain rod-to-rod spacing. A schematic of this fuel assembly containing the filler rod is shown in Figure 4.

Replacement filler rods have the same outside diameter and similar design configuration as a fuel rod. These rods also displace essentially the same volume of coolant as a fuel rod when submerged in a reactor core. Thus, the assembly lift and buoyancy forces are n[illegible]ed. However, the weight of a replacement rod is less than a fuel rod. The lower weight of a replacement rod results in an increase in the net upward force on the fuel assembly. The increase in the net upward force is well within the existing holddown spring force design margin. The fuel assembly holddown spring design is adequate to offset the net upward force increase due to fuel assembly reconstitution. The design requirement of preventing fuel assembly lift off due to an increase in the net upward force during normal operating conditions is met.

Fuel Assembly Structural Response to Seismic/LOCA Loads

The effects of seismic/LOCA faulted condition transients on the reconstituted fuel assembly were assessed. The interactions between two fuel assembly designs, reconstituted and non-reconstituted, were evaluated using the NRC-approved methodology and analytical procedures given in Reference 2.

The stainless steel filler rod has material characteristics/properties which actually strengthen the assembly structure. The filler rod does not affect the dynamic properties and impact strength of the grids. Based on the seismic/LOCA loads study discussed in WCAP 13060-P (Reference 10), the reconstituted fuel assembly loaded in the Cycle 5 core will not change the conclusions of the fuel assembly structural response found in the Vogtle updated Final Safety Analysis Report (FSAR).

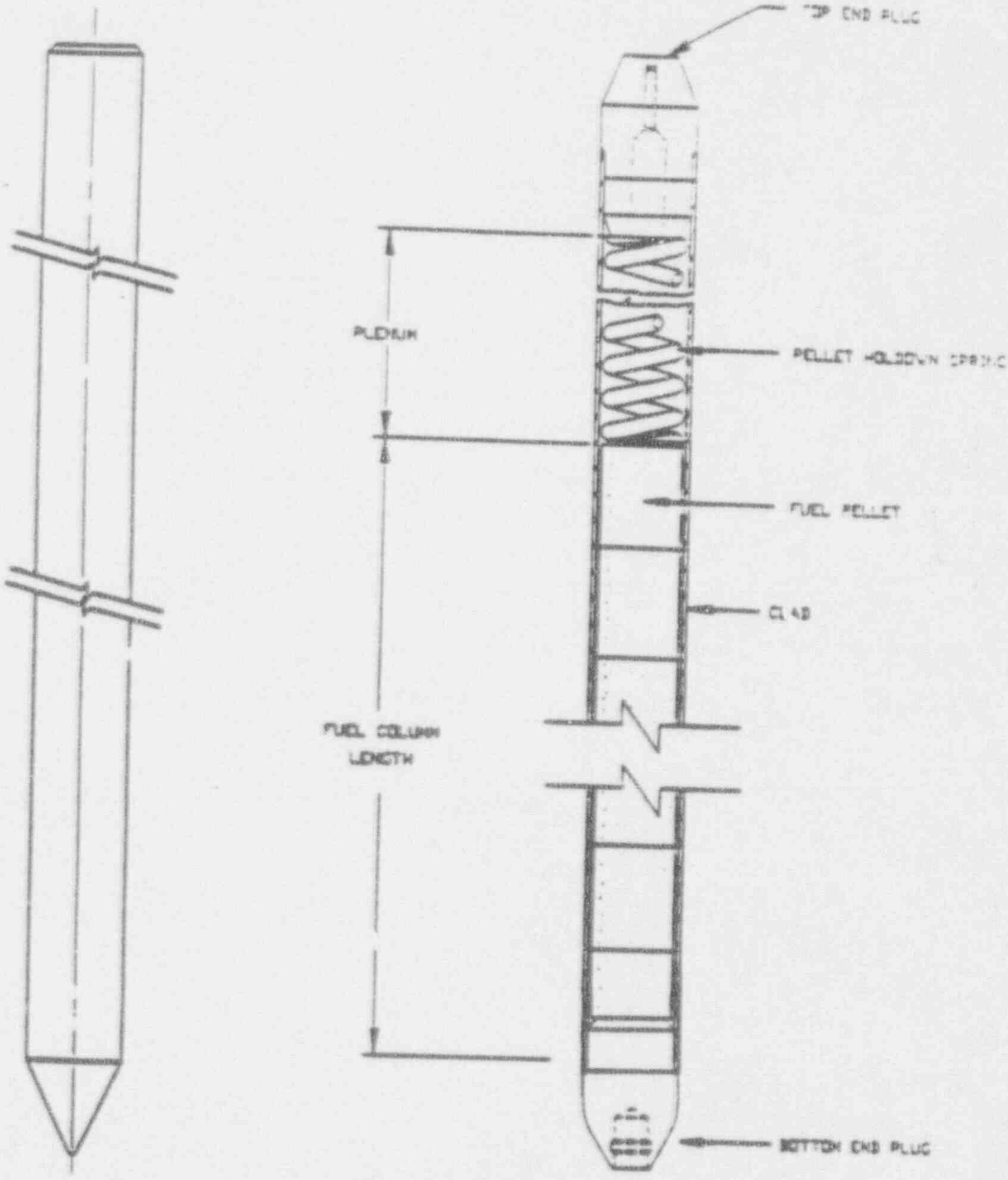
2.3 Fuel Rod Evaluation Methodology

As part of the Westinghouse reload design methods described in Reference 3, cycle-specific fuel rod design evaluations are performed using NRC-approved Westinghouse fuel performance models (Reference 7).

Fuel rod design criteria addressed by Westinghouse (References 4, 5, and 6) in these cycle-specific evaluations are not significantly impacted by fuel assembly reconstitution. The only effect of fuel assembly reconstitution on the remaining fuel rods is a very slight increase in the core average linear heat generation rate resulting from the replacement of fuel rods with inert rods. This slight increase has been evaluated and has been found to have a negligible effect with respect to fuel performance analyses as performed for Vogtle Unit 1 Cycle 5. The fuel rod design criteria are met for all remaining fuel rods in the Cycle 5 core.

Figure 3

Typical Fuel Rod and Replacement Rod

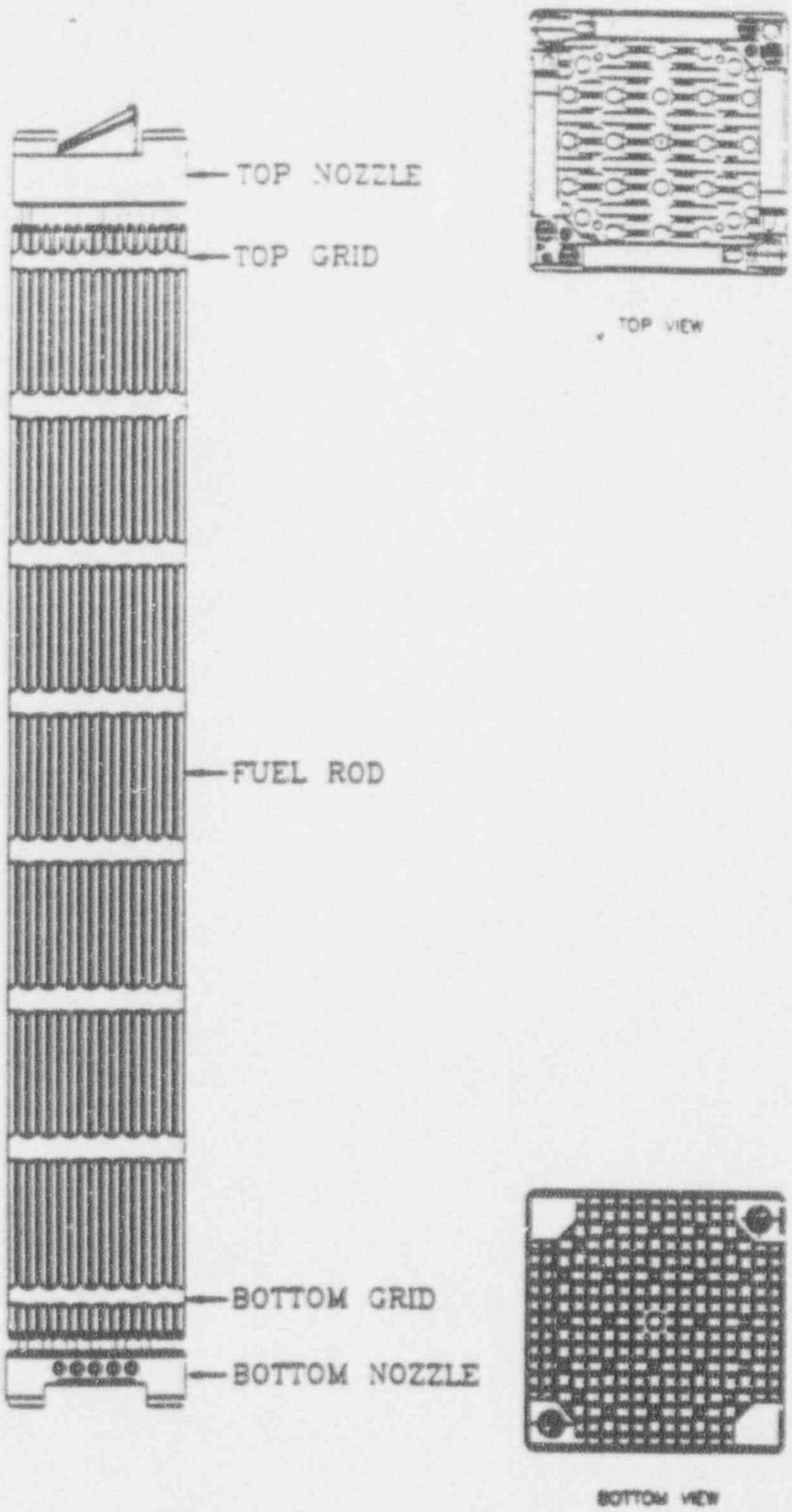


Replacement Rod

Fuel Rod

Figure 4

17x17 Fuel Assembly Outline



3.0 NUCLEAR DESIGN METHODOLOGY

3.1 Evaluation Methodology

The nuclear design evaluation was performed using NRC-approved codes and methods which are consistent with the fuel assembly reconstitution evaluation methodology currently under NRC review, Reference 10. A design evaluation, consistent with Reference 3, was performed on the Cycle 5 loading pattern containing the reconstituted fuel assembly to ensure that the design criteria for the reload are met. Fuel assembly reconstitution affects reactivity and local peaking due to the redistribution of power within the assembly. The effects of fuel reconstitution were evaluated for Cycle 5 by reviewing a list of nuclear design and key safety parameters which are based on the bounding values found in the updated FSAR. The Cycle 5 specific evaluation used standard design methods to confirm the applicability of key safety parameters.

3.2 Methodology Discussion

The effects of the reconstituted fuel assembly, which had the damaged fuel rod replaced with a stainless steel filler rod, were analyzed. The Cycle 5 specific core location for the reconstituted fuel assembly was evaluated to assess the impact on reactivity and local peaking. The nuclear design models for this evaluation were generated using current NRC-approved design methodology. Based on the results of these nuclear design models, each key safety parameter was evaluated consistent with the requirements in Reference 3. It was confirmed that the nuclear design and key safety criteria were met for the reconstituted Cycle 5 core with one filler rod.

4.0 THERMAL AND HYDRAULIC DESIGN METHODOLOGY

4.1 Evaluation Methodology

The thermal-hydraulic design evaluation of fuel assembly reconstitution for Vogtle Unit 1 was performed in accordance with the evaluation process of design criteria specified in Reference 3, using NRC approved codes and methods which is consistent with the fuel assembly reconstitution evaluation methodology currently under NRC review, Reference 10. The evaluation assessed the safety significance of fuel assembly reconstitution and assured that the reconstituted Cycle 5 core met the design criteria for the existing fuel designs.

Fuel rod reconstitution affects predictions of departure from nucleate boiling (DNB) in hot channels, due to a local power reduction and resultant enthalpy and flow changes. The DNB effects of fuel reconstitution were evaluated for Cycle 5, considering the number and location of fuel rods reconstituted. The DNB design basis in Reference 3 is applicable to the reconstituted core. The design basis in Reference 3 states that there will be at least a 95 percent probability at a 95 percent confidence level that DNB will not occur on the limiting fuel rods during normal operation and operational transients and any transient conditions arising from faults of moderate frequency (Condition I and II events). In order to meet this basis, the minimum DNB ratio (DNBR) is determined to be above the Safety Limit DNBR.

It is conservative to assume a reconstituted assembly as a regular assembly in DNB analyses because of the DNB margin gained from local power reduction in the reconstituted fuel assembly. The power reduction results in less enthalpy rise and flow increase in the reconstituted assembly. However, the reconstituted assemblies have an effect on the DNB margins of the adjacent fuel assemblies in the core.

4.2 Methodology Discussion

The DNB effects of fuel reconstitution were evaluated in Reference 10 using the THINC-IV code (References 8 and 9). Both the subchannel effects (within the reconstituted assembly) and the corewide effects (adjacent assemblies) were evaluated using THINC-IV.

Based on the study described in Reference 10 for the subchannel effects of filler rods in reconstituted fuel assemblies, DNB margin is gained from the local power reduction in the reconstituted fuel assembly. Cold wall effects on DNB due to an unheated surface from solid filler rods and coolant mixing were also

investigated in Reference 10. The Vogtle fuel assembly designs provide adequate coolant mixing with the use of mixing vane grids. The conclusions in Reference 10 regarding the cold wall effect is applicable to Vogtle Unit 1 Cycle 5 based on the fuel assembly designs and the DNB correlations used.

Fuel reconstitution may result in a flow redistribution among fuel assemblies due to a change in radial power gradient. The corewide effects on enthalpy rise and DNB were evaluated. The Vogtle reconstituted Cycle 5 loading pattern is less limiting than the evaluation in Reference 10. For Vogtle Unit 1 Cycle 5, the corewide effects are negligible.

Fuel reconstitution may also affect the core average heat flux due to a reduced heat transfer area. However, one solid filler rod replacing the damaged fuel rod in the Vogtle Unit 1 Cycle 5 loading pattern had a negligible effect on DNB due to the slight increase in core average heat flux. The specific evaluations which were performed for Vogtle Unit 1 Cycle 5, considering the exact configuration and associated core power distribution of the reconstituted assembly, confirmed that the reconstituted assembly was bounded by a regular assembly in DNB analyses and the DNB design basis was met.

5.0 NON-LOCA METHODOLOGY

5.1 Non-LOCA Evaluation Methodology

Reload safety analyses were performed for Vogtle Unit 1 Cycle 5 in accordance with the reference analysis approach discussed in Reference 3. This process confirms whether or not a core configuration is bounded by the existing safety analyses, and verifies that applicable safety criteria are satisfied for the reload design. For those cases in which the existing safety analyses prove to be no longer bounding, the process also identifies the potentially impacted licensing basis events.

The methodology systematically identifies parameter changes on a cycle-by-cycle basis which may invalidate existing safety analyses and identifies those events which need to be evaluated. If a parameter is only slightly out of bounds, or the transient is relatively insensitive to that parameter, a simple qualitative evaluation may be made which conservatively evaluates the magnitude of the effect and explains why the actual analysis of the event does not have to be repeated. Alternatively, should the deviation be large and/or expected to have a more significant or not easily quantifiable effect on the analysis, a reanalysis of the accident is performed. If the accident is reanalyzed, the analysis methods follow standard procedures and will typically employ analytical methods which have been used and approved in previous submittals to the NRC. These methods are those which have been presented in the FSAR, subsequent submittals to the NRC for a specific plant, reference SARs, or reports submitted for NRC approval.

The reload evaluation process has been expanded to facilitate the evaluation of new or modified fuel designs. This is accomplished as specified in the Standard Review Plan (SRP) Section 4.2 (Reference 1), Subsection ""', "For operating license (OL) applications, the review should confirm that the design bases set forth in the Final Safety Analysis Report (FSAR) meet the acceptance criteria given in Subsection II A" of SRP 4.2, "and that the final fuel system design meets the design bases.". The SRP Section 4.2 complements the reload safety reanalysis methodology by outlining a process and establishing acceptance criteria for enabling the evaluation of new or modified fuel designs which may be incorporated in the reload cores. Provided that the new or modified fuel design meets the criteria specified in the SRP Section 4.2, NRC review and approval is not necessary. The SRP Section 4.2 allows for 10CFR50.59 conclusions to be reached by demonstrating that the criteria defined in the SRP Section 4.2 are used for the evaluation

of the fuel mechanical change(s) such as reconstitution and are met. The only change that will be needed to the Technical Specifications is in the Design Features Section 5.3.1, currently under NRC review.

The reload safety analysis methodology as described by Reference 3, systematically identifies reload core changes on a cycle-by-cycle basis as well as changes in fuel design which may invalidate existing safety analyses. The process also identifies those licensing basis events that need to be re-evaluated should this be necessary.

5.2 Methodology Discussion

A review was made of all of the criteria (design parameters) found in the SRP (Reference 1). The SRP design parameters were reviewed for adequacy and completeness in view of the proposed Vogtle Unit 1 Cycle 5 fuel assembly reconstitution. The SRP design parameters which may be impacted due to fuel reconstitution and which may have an adverse impact on the non-LOCA licensing basis analyses were evaluated.

These design parameters are of primary importance in the non-LOCA licensing basis analyses due to the assumptions and licensed methods which are currently used. The potential for impact results from the removal of fuel rods which will increase the core average kw/ft (for a given power level). This in turn will increase nominal fuel temperatures and fuel rod heat flux.

Increases in the nominal fuel and clad temperatures and fuel rod heat flux may impact the non-LOCA licensing basis analysis results for peak fuel and clad temperatures as well as the margin to the critical heat flux (minimum DNBR). The SRP criteria above include all of these potential effects. It has been concluded that these design parameters are adequate for evaluating the non-LOCA analysis impact of the proposed fuel reconstitution for Vogtle Unit 1 Cycle 5. These design parameters were evaluated for the reconstituted Cycle 5 core as part of the reload process (Reference 3). The results of the reload analysis verified that the conclusions of the non-LOCA accidents in the Vogtle updated FSAR remain valid.

6.0 LOCA METHODOLOGY

6.1 LOCA Evaluation Methodology

Changes to the Vogtle Unit 1 Cycle 5 fuel were evaluated to assure that the licensing basis analyses remain valid with the use of a filler rod. The Reload Methodology described in Reference 3 was followed to assure that fuel parameters significant to the Emergency Core Cooling System (ECCS) analyses remain bounded or acceptable with respect to comparable analysis parameters values.

Reconstitution of a Vogtle Unit 1 Cycle 5 fuel assembly represents a change to the fuel which can be addressed in the context of the reload evaluation. The Standard Review Plan (Reference 1)(Section 4.2, Subsection III) specifies that "the review should confirm that the design bases set forth in the Final Safety Analysis Report (FSAR) meet the acceptance criteria given ... and that the final fuel system design meets the design bases." By evaluating potential effects of reconstitution on the licensing basis analysis, anticipated changes in analysis results can be quantified and tracked during residence time for which the reconstituted fuel assembly is in the core. The result of this evaluation is the confirmation of continued compliance with acceptance criteria of 10CFR50.46.

The steady state and transient effects of reconstituted assemblies on large and small break loss-of-coolant accident (LOCA) analyses are described in WCAP-13060-P (Reference 10). An evaluation of the potential effects of reconstitution on the ECCS analyses was performed to demonstrate continued compliance to the acceptance criterion of 10CFR50.46. The methodology by which reconstitution of a Vogtle Unit 1 Cycle 5 fuel assembly was evaluated is described below.

6.2 Methodology Discussion

The following LOCA evaluation methodology is defined for application to Vogtle Unit 1 Cycle 5:

1. For reconstitution with stainless steel filler rods, a limiting case of the stainless steel filler rods will be conservatively assumed.

2. The Vogtle Unit 1 Cycle 5 steady state evaluation resulted in a negligible increase in Peak Clad Temperature (PCT) for the Large Break LOCA (LBLOCA). Therefore, a conservative penalty of 1°F will be assessed to cover the steady state effects for the LBLOCA.

3. Based on the number of damaged fuel rods replaced, the potential increase in linear heat rate required to retain total core power constant at its rated value was calculated. This change was evaluated for Vogtle Unit 1 Cycle 5 which resulted in a conservative assessment of a 1°F PCT penalty for both LBLOCA and the Small Break LOCA (SBLOCA).

The LBLOCA and SBLOCA PCT affect of 2°F and 1°F, respectively, will be added to the sum of the evaluations performed to date, and the calculated PCT for the Vogtle plant as analyzed with respect to 10 CFR 50.46 reporting requirements. This reconstitution penalty will be tracked throughout the period of core residence for the affected assembly. Upon removal of the reconstituted assembly at a future Vogtle reload, the penalty will be removed from the Vogtle assessment against PCT margin. It should be noted that the PCT effects calculated for reconstitution are considered to be due to plant changes and not due to ECCS evaluation model changes. The absolute value of these changes will not be considered in the cumulation of changes to the Evaluation Model for purposes of determining if the cumulation of changes is significant as defined by 10CFR50.46.

With respect to the Standard Review Plan (Reference 1) (Section 4.2, Subsection III), assurance of adequate PCT margin for these small penalties was confirmed. This approach answers directly the criterion regarding changes to the LOCA fuel clad peak temperature. The methodology, as described and developed, also allowed the analyst to make an evaluation on each of the other LOCA related criteria which showed no change to fuel rod clad rupture, extent of blockage to assure fuel coolability and structural response to LOCA loads. Presuming ongoing tracking and available margin, this will be an adequate treatment for use in the Vogtle Unit 1 Cycle 5 reload. On the basis of these findings, the Vogtle Unit 1 Cycle 5 reconstitution can be licensed with respect to the LOCA analysis (SBLOCA and LBLOCA) under the auspices of 10CFR50.59 per the evaluation process discussed above.

7.0 REFERENCES

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