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ADVANCED NUCLEAR FUELS CORPORATION

THERMAL HYDRAULIC COMPATIBILITY ANALYSIS OF ANF HIGH THERMAL PERFORMANCE FUEL FOR H.B. ROBINSON, UNIT 2

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1.0 INTRODUCTION AND SUMMARY

1.1 Introduction

This report documents the results of analyses to 1) address the thermal hydraulic compatibility of Advanced Nuclear Fuels (ANF) high thermal performance (HTP) fuel assemblies with the co-resident ANF standard mixing vane (SMV) fuel assemblies in the H.B. Robinson, Unit 2 core, 2) evaluate the relative severity of the limiting transients for the Cycle 14 core configuration, and 3) demonstrate that margin exists with this fuel design over a range of possible axial power distributions.

As part of a general thermal hydraulic compatibility analysis the HTP fuel is evaluated relative to

1. core MDNBR,
2. control rod insertion characteristics,
3. control rod guide tube coolability,
4. core bypass flow,
5. fuel rod bowing, and
6. fuel centerline temperature.

Because the guide tube and fuel dimensions for the HTP and SMV assemblies are identical, the above items 2, 3, 4 and 6 will not be impacted. Thus, only the above items 1 and 5, core MDNBR and fuel rod bowing, are evaluated.

1.2 Summary

Results of XCOBRA-IIIC calculations performed to estimate the core MDNBR for future mixed configurations of HTP and SMV assemblies are summarized in Table 1.1. The core conditions for the loss-of-load transient were used for all cases and the core loading patterns and assembly relative powers for Cycle 14 were utilized. The HTP assembly DNBR values were calculated using the ANFP correlation (Ref. 1) while the SMV DNBRs were calculated using the XNB correlation (Ref. 2). The peak power assembly was assumed to be at the $F_{\Delta H}^{N}$ Technical Specification limit of 1.65. An SMV assembly is the peak power assembly only for the early portion of the first mixed core cycle. Table 1.1 also notes the nominal and mixed core MDNBR limits for each correlation.

The calculations indicate the use of HTP assemblies will not result in a core MDNBR below the mixed core, 95/95 correlation limit for either the SMV or HTP assemblies

The results show that a considerable gain in core MDNBR (or $F_{\Delta H}^{N}$) will be realized for future cycles in which an HTP assembly is the peak power (limiting) assembly.

There is no impact on the MDNBR due to rod bowing.

The MDNBR values for Cycle 14 for the three most limiting Chapter 15 events are summarized in Table 1.2. As seen the loss-of-load transient remains the limiting transient for both the SMV and HTP assemblies.

The MDNBR values for the four worst case axial power profiles (from previous set point analyses) were evaluated for the loss-of-load transient. The results are summarized in Table 1.3 and confirm that the current setpoint trip function remains bounding for Cycle 14.

Table 1.1. Limiting transient (loss-of-load) MDNBR values for HTP and SMV fuel assemblies vs. mixed core configuration.

	MDNBR for SMV Assembly	MDNBR for HTP Assembly
All SMV Core		
First Reload 1/3 HTP Assemblies, 2/3 SMV Assemblies		
Second Reload 2/3 HTP Assemblies, 1/3 SMV Assemblies		
All HTP Core		

Table 1.2. MDNBR values for the three most limiting Chapter 15 Events (Cycle 14 core configuration).

Transient	SMV Assembly MDNBR (1)	HTP Assembly MDNBR (2)
Loss-of-load		
Control rod withdrawal		
Control rod drop		

Table 1.3. MDNBR values for the four most limiting axial power profiles (loss-of-load transient, Cycle 14 core configuration).

Transient	SMV Assembly MDNBR (1)	HTP Assembly MDNBR (2)
Axial 1		
Axial 2		
Axial 3		
Axial 4		

2.0 THERMAL HYDRAULIC CHARACTERIZATION OF HTP AND SMV FUEL ASSEMBLIES

Comparison of the spacer configuration for HTP and SMV assemblies is shown in Figure 1. The HTP configuration represents a significant design change relative to the SMV grid configuration. The IFMs result in an abrupt change in hydraulic resistance between the HTP and adjacent SMV assemblies which will affect the cross-flow between assemblies. Also, the different hydraulic resistance of the spacer grids will also influence the assembly cross flow. The characteristics of the HTP and SMV fuel assemblies are summarized in the following subsections.

2.1 Thermal Characterization of HTP and SMV Assemblies

The HTP spacer grids and IFMs have been shown in Tables 1.1 and 1.2 to provide a significant increase in the thermal margin (MDNBR) for H. B. Robinson, Unit 2. The thermal characteristics of the HTP assemblies have been extensively quantified via critical heat flux tests which were used to develop the ANFP DNB correlation (Ref. 1). The ANFP correlation was used to calculate the MDNBR for the HTP assemblies. The DNBR for the SMV assemblies were evaluated using the XNB correlation (Ref. 2) as in previous H. B. Robinson, Unit 2 fuel cycles.

2.2 Pressure Drop Characterization of HTP Assemblies

Component hydraulic loss coefficients for the HTP and SMV assemblies are compared in Table 2.1. The HTP data were measured in tests performed in ANFs portable loop hydraulic test Facility (Ref. 3). The SMV assembly spacer loss coefficient is documented in Reference 4. The loss coefficients are for the liquid phase and are referenced to the in-reactor, bare rod flow area. The upper and lower tie plate loss coefficients include reversible losses due to area change and losses due to simulated upper and lower core support structures. The overall assembly loss coefficient for the HTP and SMV assemblies are compared in Figure 2.

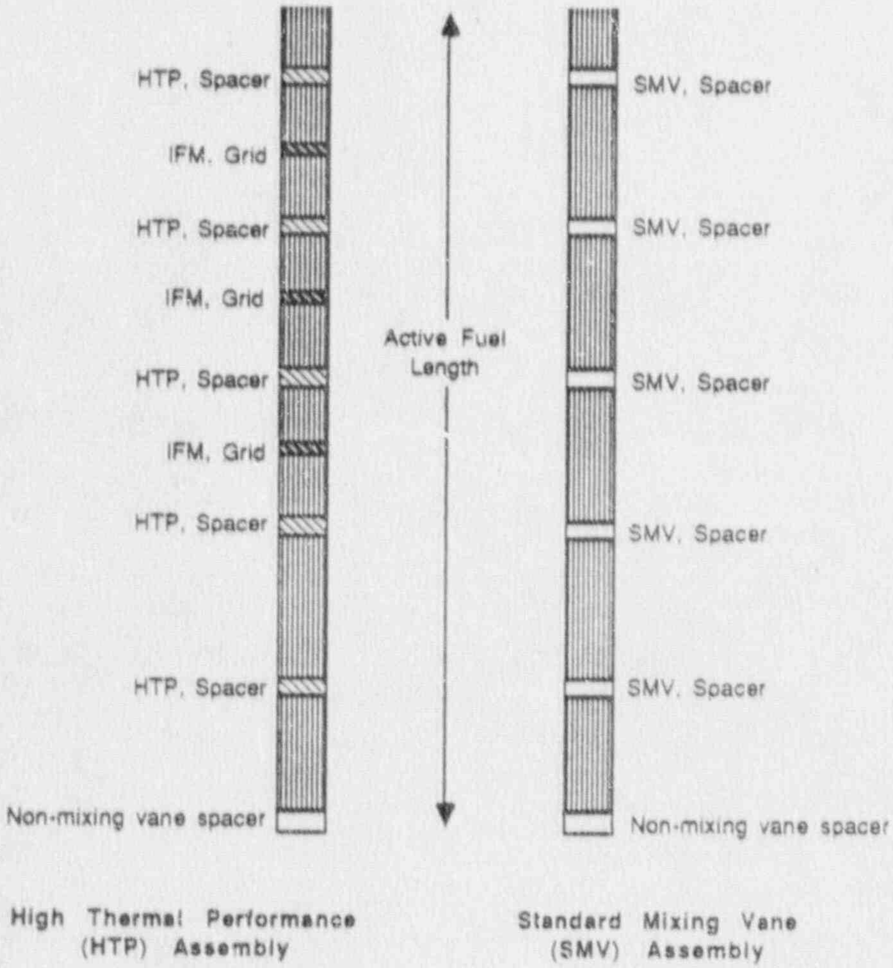


Figure 1. HTP vs SMV grid configuration.

Table 2.1. Comparison of SMV and HTP Pressure Loss Coefficients (values for in-reactor application)

Figure 2. Distribution of pressure loss coefficients for SMV and HTP Robinson fuel assemblies (evaluated at Re=500,000 for in-reactor values)

3.0 XCOBRA-IIIC THERMAL HYDRAULIC ANALYSIS

The ANF mixed core methodology (Ref. 5) was used in calculating the core MDNBR.

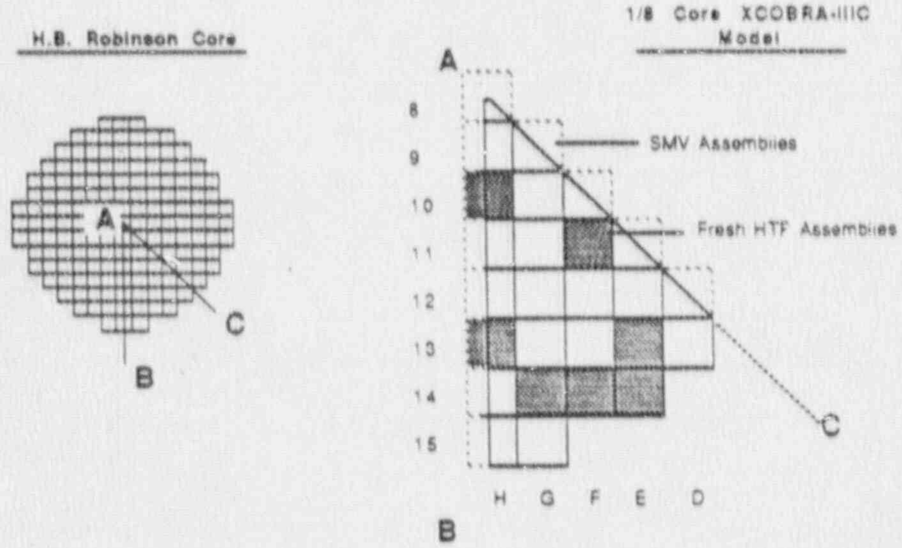
The XCOBRA-IIIC core and hot fuel assembly models are briefly discussed in the next two subsections.

3.1 XCOBRA-IIIC Core Model

The core flow distribution analysis is performed to assess crossflow between assemblies and to quantify the flow vs axial distance for each fuel assembly. The core flow distribution analysis is particularly important for mixed fuel loadings where hydraulically different fuel types are co-resident in the core. The core model calculates the coolant mass and momentum flux vs axial distance for subsequent hot fuel assembly calculations to determine the core MDNBR.

The XCOBRA-IIIC core model represents each fuel assembly in a 1/8 symmetric core sector of the H.B. Robinson, Unit 2 core as shown in Figure 3. Each fuel assembly is modeled as an individual hydraulic channel.

(a) first HTP reload
(Cycle 14)



(b) second HTP reload

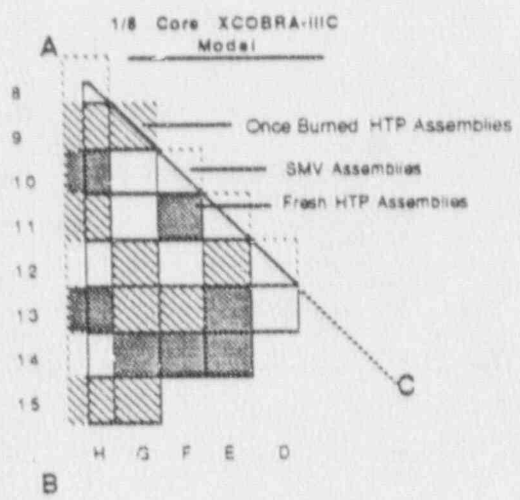


Figure 3. XCOBRA-IIIC Core Flow Model

Cross flow between adjacent assemblies in the open lattice cor is directly modeled. The single-phase loss coefficients of Table 2 1 are used.

As noted earlier, the calculations utilized the thermal hydraulic boundary conditions associated with the H. B. Robinson, Unit 2 limiting (loss-of-load) transient transient and a axial power profile. The peak fuel assembly is adjusted to be at the Technical Specification limit of 1.65.

The following core configurations were modeled:

1. all SMV fuel assemblies (for reference)
2. first cycle HTP loading configuration
3. second cycle HTP loading configuration, and
4. all HTP fuel assemblies.

3.2 Peak Fuel Assembly Model

The XCOBRA-IIIC peak fuel assembly model is a symmetric 1/8 assembly sector as shown in Figure 4. Heat, mass, and momentum fluxes between the inter-rod flow channels are explicitly calculated. Local values of mass flux and enthalpy are determined, and sed to calculate the DNBR. Coolant mass and momentum flux vs axial position calculated from the core model are used as boundary conditions to the outer, vertical boundary of the assembly.

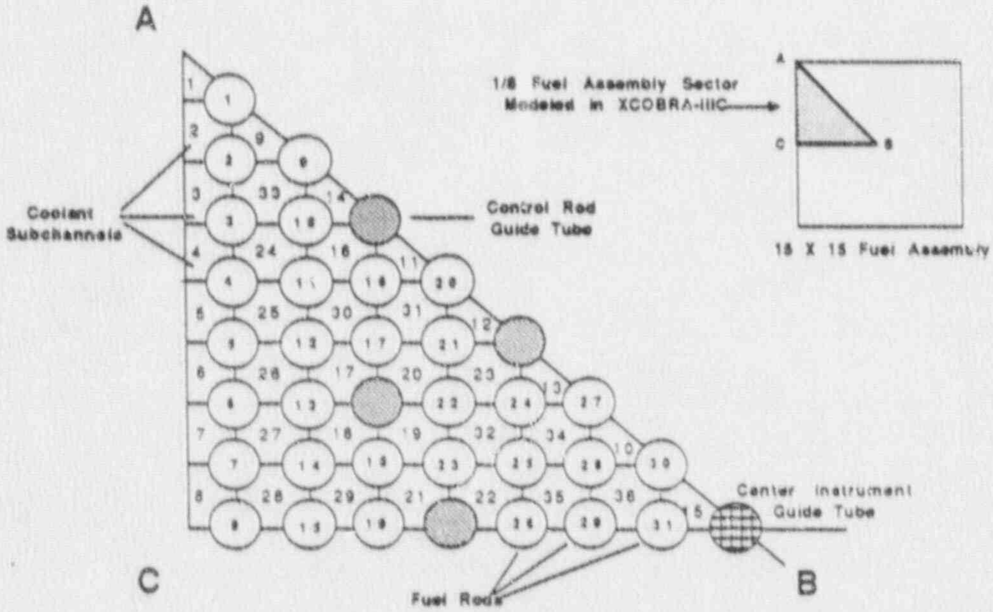


Figure 4. XCOBRA-IIIC Hot Fuel Assembly Model.

The fuel rod relative power distribution from a previous H. B. Robinson, Unit 2 analysis (Ref. 6) was used and represents a conservative profile relative to bundle power and flows.

3.3 Calculated MDNBR Values

The calculations utilize the core thermal/hydraulic boundary conditions for the loss-of-load (limiting) transient.

The calculated MDNBR values for the mixed core configuration cases considered are summarized in Table 1.1 (included in Section 1.0).

4.0 ROD BOWING IMPACT ON MDNBR

The impact of rod bowing on the HTP MDNBR values was evaluated using the ANF Rod Bowing Methodology (Ref. 7).

5.0 EVALUATION OF LIMITING TRANSIENTS FOR CYCLE 14

Previous safety analysis work has shown the three most limiting Chapter 15 events are,

- loss-of-load
- control rod withdrawal
- control rod drop.

XCOBRA-IIIC calculations were performed to evaluate the MDNBR values for each of these transients for both the SMV and HTP assemblies for the core configuration of Cycle 14 (Figure 3[a]). The results are summarized in Table 1.2 (included in Section 1.0). The calculations indicate that the limiting transient for both fuel types is the loss-of-load transient. Also, the relative MDNBR values show the same trend for both type assemblies.

6.0 EVALUATION OF LIMITING AXIAL POWER PROFILES FOR CYCLE 14

The axial power profiles are a key parameter in assessing the acceptability of the reactor OTΔT set point. Previous set point analyses have established the axial power profiles that, together with the limiting transient core boundary conditions, yield the most limiting MDNBR values for the set point evaluation.

Calculations were performed to determine the Cycle 14 limiting transient (loss-of-load) MDNBR using these limiting axial power profiles for both the SMV and HTP assemblies modeled as the limiting $F^N_{\Delta H}$ assembly. The results are summarized in Table 1.3 (included in Section 1) and confirm that the limiting SMV assembly MDNBR values are greater than the mixed core 95/95 MDNBR limit.

The results of the axial power shape sensitivity calculations confirm that the current OTΔT trip setpoint will continue to be valid for Cycle 14.

7.0 REFERENCES

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