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Application of the ANFB Critical Power Correlation to Coresident GE Fuel for LaSalle Unit 2 Cycle 8

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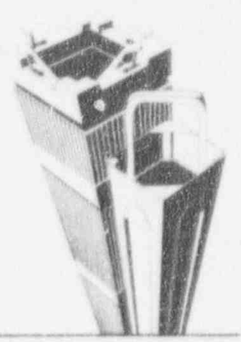

Siemens Power Corporation

Nuclear Division

Siemens Power Corporation - Nuclear Division

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Application of the ANFB Critical Power Correlation to Coresident GE Fuel for LaSalle Unit 2 Cycle 8

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February 1996

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1	2-2	Typographical errors (minor) corrected.

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Application of the ANFB Critical Power Correlation to Coresident GE Fuel for LaSalle Unit 2 Cycle 8

1.0 INTRODUCTION AND SUMMARY

Starting with Cycle 8, Siemens Power Corporation - Nuclear Division (SPC) will supply the fresh fuel assemblies for LaSalle Unit 2. However, previously exposed GE9 fuel will remain coresident with the SPC fuel during the transition cycles. The NRC-approved ANFB critical power correlation described in Reference 1 will be used in establishing and monitoring Minimum Critical Power Ratio (MCPR) limits for both SPC fuel and the coresident GE9 fuel. As a result, justification of the applicability of the ANFB critical power correlation to GE9 fuel is required. This report describes the application of the ANFB critical power correlation to the coresident GE9 fuel which will be present in LaSalle Unit 2 Cycle 8.

For the ANFB correlation, the critical power is based on assembly hydraulic conditions and on local power peaking about each rod. The local power peaking dependency is characterized by the F-eff parameter which includes a component referred to as the additive constant. Additive constants are used to address effects on critical power performance due to different design features (primarily spacers) between assembly types. The additive constants are determined based on test data according to the procedures described in Reference 1. The uncertainties in the additive constants are used in the NRC-approved MCPR safety limit methodology described in Reference 2 to ensure that less than 0.1% of the fuel rods are in boiling transition during anticipated operational occurrences.

The ANFB critical power correlation includes test results for many different fuel designs in its database, including fuel from other vendors. However, when the coresident fuel in a transition cycle is not part of the existing database, an alternate process is used to establish the additive constants and uncertainty consistent with the approved SPC methodology. The alternate process used to determine additive constants and uncertainty for coresident fuel not included in the ANFB database is described in Reference 3 and has been submitted to the NRC.

In the alternate process, the additive constants for coresident fuel types are established using calculated CPR data provided by the utility. [

]

For fuel types in the ANFB database, the additive constant uncertainty is determined directly by comparing ANFB predictions to test data. For coresident fuel that is not part of the ANFB database, the additive constants are developed based on calculated critical power data as discussed above. The calculated data are obtained from an approved critical power correlation based on test data applicable to the coresident fuel. [

]

Although some critical power data for early GE9 designs are available to SPC, SPC does not consider the data to be sufficient to justify additive constants appropriate for the current GE9 fuel design. Therefore, additive constants for GE9 fuel were developed using the alternate process described in Reference 3 and calculated critical power data provided by Commonwealth Edison Company (ComEd). This report documents analyses performed to determine the additive constants and uncertainty which can be used with the ANFB critical power correlation to predict the CPR performance of GE9 fuel.

Table 1.1 summarizes the ANFB additive constants and uncertainty developed for GE9 fuel. The additive constants result in conservative MCPR monitoring for GE9 fuel at rated conditions over the exposure range where the coresident fuel has the potential to be limiting or near limiting. Although insensitive to the value of the additive constant, the uncertainty in the additive constants is important in the MCPR safety limit analysis. The process used to

determine the additive constant uncertainty results in a conservative value relative to the Reference 1 process, which is used when critical power test data are directly available.

Because the coresident GE fuel is in its second or higher cycle of operation, it inherently has greater MCPR margin. This greater MCPR margin combined with the conservative method of developing additive constants and additive constant uncertainties for the coresident fuel ensures that the coresident fuel will be nonlimiting relative to the SPC fuel (i.e. the coresident GE fuel will have more margin to boiling transition during potential transients).

Table 1.1

ANFB Additive Constants for GE9 Fuel Assemblies

[

]

Additive Constant Uncertainty = [ ]

2.0 GE9 ADDITIVE CONSTANT DEVELOPMENT

Data specifically for LaSalle GE9 fuel are not contained in the ANFB critical power correlation measured database; therefore, additive constants were developed based on comparisons to predicted results using the process described in Reference 3. The process involved [

].

An initial set of additive constants was used to determine nodal F-eff values for use with the ANFB correlation. Single assembly CPR calculations using the SPC plant simulator code MICROBURN-B were performed for fuel assemblies with power, exposure, inlet enthalpy, pressure, and active channel flow conditions consistent with the calculated data provided by ComEd. [

] Results showing ANFB calculated CPR lower than the corresponding GEXL calculated CPR indicate that applying the ANFB correlation is conservative since use of the ANFB correlation would put the fuel assembly closer to the MCPR limit.

The ANFB additive constants for GE9 fuel were established using the approved process described in Reference 1 with the exception that [

]. Two constraints were imposed on the additive constants: (1) the same set of additive constants was used for each of the GE9 neutronic designs analyzed (seven total), and (2) within the additive constant array, the same additive constant was used at rod positions that are in similar locations relative to the channel wall, water rod, and other fuel rods. Since several of the characteristic rod groups were never limiting, adjustments were made in the nonlimiting rod groups to ensure that future GE9 neutronic designs do not reduce the conservative nature of the additive constants selected. The additive constants for nonlimiting rod positions were set to force rods in nonlimiting rod positions to the point where

they are very nearly limiting. Adjusting the additive constants in this manner ensures that the resulting F-eff will be conservative in nuclear designs that have different limiting rod positions.

The analyses performed to determine GE9 additive constants included evaluating the use of the ANFB critical power correlation over a wide range of operating conditions. Calculations were made for fuel assemblies with a range of exposure, power, and flow conditions, in both uncontrolled and controlled states. The input conditions used in the analyses cover the ranges of expected operating and accident conditions.

The additive constants developed for the GE9 fuel assembly are shown in Table 1.1. Comparisons of the CPR predicted by ANFB and GEXL for GE9 fuel are presented in Figures 2.1 and 2.2. Figure 2.1 presents a direct comparison of the CPR predicted by ANFB and GEXL. Figure 2.2 presents the fractional difference between GEXL predicted CPR and the corresponding ANFB predicted CPR as a function of assembly exposure. The results show that using the additive constants presented in Table 1.1 with the ANFB critical power correlation generally results in a conservative CPR prediction for GE9 fuel assemblies relative to the CPR predicted by GEXL.

A summary of the statistical comparison between the CPR predicted by ANFB and GEXL is provided in Table 2.1. The results indicate that ANFB predictions have a conservative bias of [ ] relative to GEXL for GE9 fuel. The standard deviation between ANFB and GEXL predicted CPR is [ ]. Note, this standard deviation includes more than just the correlation-to-correlation variability. Implicit in the statistical comparison is the variability of the SPC and GE lattice physics codes. Local peaking used in the GEXL CPR calculations is based on the TGBLA computer code while local peaking used in the ANFB CPR calculations is based on the CASMO computer code. Because the uncertainty in the lattice physics code is explicitly accounted for in the MCPR safety limit methodology, an additional level of conservatism is introduced by associating the observed [ ] standard deviation entirely to ANFB-GEXL correlation differences.

Table 2.1

Statistical Comparison Between
CPR Calculated by ANFB and GEXL at
Equivalent Operating Conditions

$$X = \frac{CPR_{ANFB}}{CPR_{GEXL}}$$

$$\bar{X} = [\qquad]$$

$$\sigma_X = [\qquad]$$

$$Y = \frac{CPR_{GEXL} - CPR_{ANFB}}{CPR_{GEXL}}$$

$$\bar{Y} = [\qquad]$$

$$\sigma_Y = [\qquad]$$

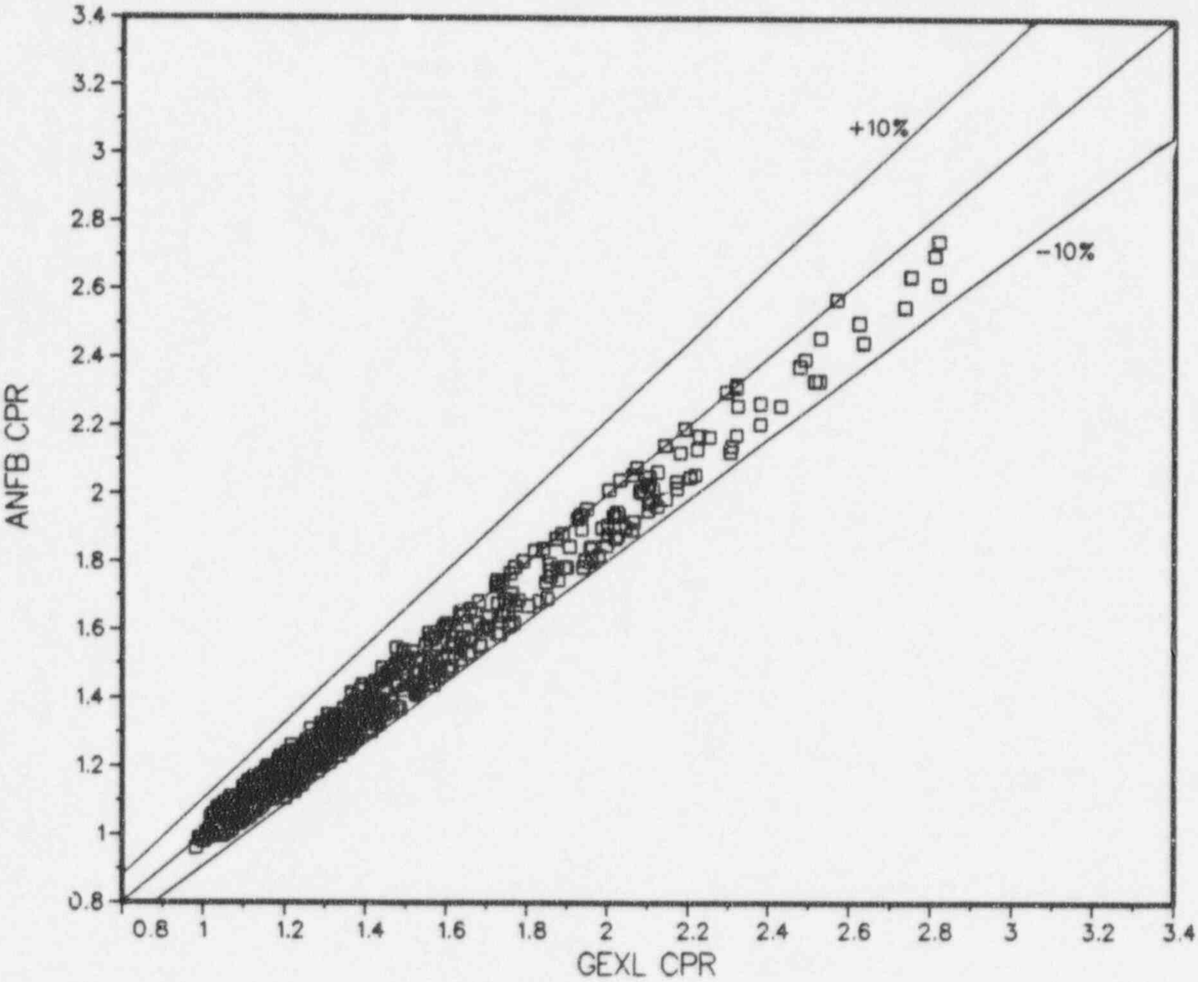

Figure 2.1

Comparison Between CPR Calculated by ANFB and GEXL at Equivalent Operating Conditions

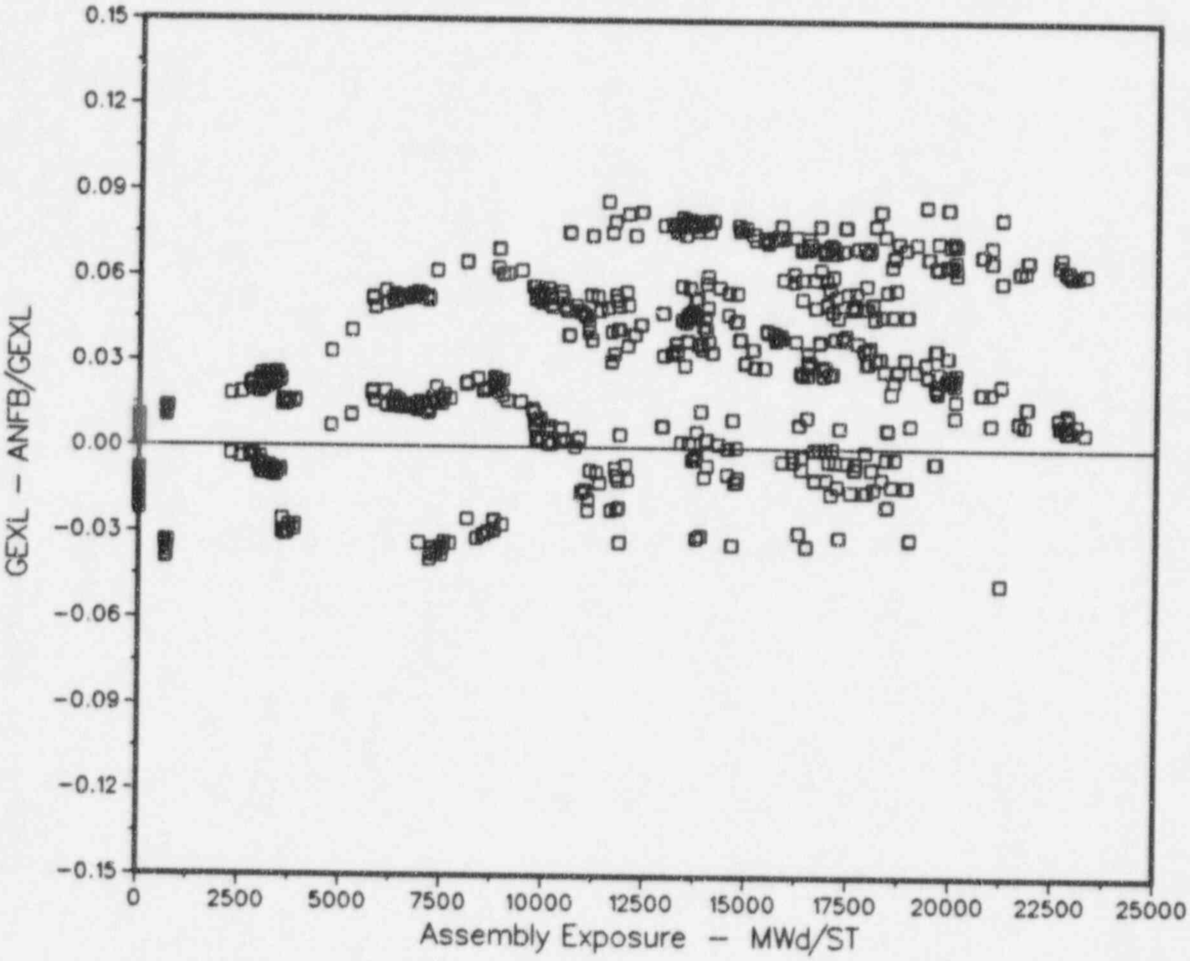

Figure 2.2

Fractional Difference Between CPR Calculated by ANFB and GEXL at Equivalent Operating Conditions

3.0 GE9 ADDITIVE CONSTANT UNCERTAINTY

The uncertainty (standard deviation) for the additive constants is required to establish MCPR limits. For SPC fuel, the additive constant uncertainty is determined directly by comparing ANFB predictions to test data. Because GE9 fuel is not part of the ANFB database, the additive constants were developed based on calculated critical power data as described in Section 2.0. [

]

The process used to determine the additive constant uncertainty for the coresident GE9 fuel is described in Reference 3.

[

]

[

] The GEXL correlation uncertainty applicable for GE9 fuel is 3.6%. This value was obtained from Reference 4 and has been confirmed by ComEd. [

] The resulting standard deviation is shown on the following page.

[ ]

The final step in determining the ANFB additive constant uncertainty for use with GE9 fuel is to convert the total CPR standard deviation into the additive constant standard deviation for use in the approved safety limit methodology described in Reference 2. For ANFB, the CPR standard deviation is [ ] times the additive constant standard deviation as described in Reference 3. Using this relationship, the ANFB additive constant uncertainty appropriate for GE9 fuel is shown below.

[ ]

As demonstrated in Reference 3, determining the additive constant uncertainty in this manner results in a larger uncertainty than would be obtained if the ANFB correlation were compared directly to the critical power test data for the GE9 fuel. Therefore, when the combined standard deviation is used in the approved SPC safety limit methodology, the GE9 fuel will be treated in a manner that results in a conservative prediction of the margin to actual boiling transition.

4.0 EXPECTED IMPACT ON SAFETY ANALYSES

SPC will perform safety analyses to establish MCPR operating limits for the GE fuel present in the LaSalle transition cycles. The additive constants documented in this report will be used with the ANFB correlation to monitor the GE9 fuel.

The MCPR operating limit for GE9 fuel at LaSalle will be established by adding the ΔCPR for the limiting event to the MCPR safety limit for the cycle. ΔCPR is relatively insensitive to the value of the additive constants. The additive constant uncertainty is considered in the MCPR safety limit and does not affect the ΔCPR calculation methodology.

In the MCPR safety limit analysis, the core power is increased until the MCPR safety limit is reached for the limiting fuel assembly. Monte Carlo calculations are performed to assess the impact of the uncertainties of various plant and analysis parameters. The Monte Carlo calculations establish the MCPR safety limit at which 99.9% of the rods are expected to avoid boiling transition. Because the limiting assembly is forced to the safety limit, the value of the additive constant is relatively unimportant in the safety limit analysis. The additive constant uncertainty is considered in the Monte Carlo analysis.

The additive constant values and uncertainty documented in this report will be applied only to GE9 fuel with at least one cycle of exposure. The MCPR safety limit analysis is performed at various exposures throughout the cycle to ensure a bounding safety limit for the cycle. Because the MCPR safety limit is primarily controlled by high power first cycle fuel (especially at the end-of-cycle conditions normally limiting for the safety limit), the safety limit is expected to be relatively insensitive to the additive constant uncertainty used for GE9 fuel and in many cases will not have any effect on the safety limit (i.e., GE9 fuel in its second or higher cycle of operation will not contribute to the number of rods in boiling transition). Preliminary safety limit analyses performed for LaSalle 2 Cycle 8 indicate that at the limiting exposure, the GE9 fuel does not contribute to the number of rods calculated to be in boiling transition.

5.0 EXPECTED MCPR MARGIN FOR GE9 FUEL IN LASALLE UNIT 2 CYCLE 8

For most transition cycles, the coresident fuel will have significant MCPR margin to the fresh fuel due to the lower power of the higher exposed coresident fuel. This is especially true at end-of-cycle (EOC) conditions where transients are generally most limiting (i.e., minimum margin to the safety limit). Table 5.1 provides a comparison of the difference in MCPR between the fresh SPC fuel and the once burned GE fuel for the LaSalle Unit 2 Cycle 8 preliminary core loading plan. The MCPR for the SPC fuel is based on the ANFB correlation while the MCPR for the once burned GE fuel is based on the GEXL correlation. The MCPR results in Table 5.1 were determined by ComEd to illustrate the significant steady-state MCPR difference between SPC and GE9 fuel based on the approved correlation for each fuel type. The final core loading plan for Cycle 8 may be slightly different than the preliminary plan, but the MCPR differences between the SPC and GE fuel are not expected to change significantly. The MCPR differences are on the order of 100% (at BOC) to 250% (at EOC) of the expected ΔCPR for the fresh SPC fuel.

Both the MCPR safety limit and the transient ΔCPR response are most limiting near EOC. Because the MCPR operating limit for the entire cycle is based on the limiting exposure conditions, significant margin exists to the safety limit for both SPC and GE9 fuel during transients early in the cycle. As shown in Table 5.1, throughout the cycle and especially at EOC, GE9 fuel will have significantly greater initial MCPR margin to the safety limit than for SPC fuel. As discussed in Section 4.0, the GE9 coresident fuel is not expected to contribute to the number of fuel rods calculated to be in boiling transition when the core is at the MCPR safety limit. These inherent margins for the GE9 fuel combined with the conservative method of developing additive constant uncertainties ensures that the GE9 fuel will be nonlimiting relative to the SPC fuel (i.e. GE9 fuel will have more margin to boiling transition during potential transients).

Table 5.1

SPC Fuel (ANFB) and GE9 (GEXL) MCPR Data for LaSalle Unit 2 Cycle 8 Preliminary Core Design

Exposure (MWd/MTU)	MCPR GE9 Fuel	MCPR SPC Fuel	ΔMCPR (GE9 − SPC)
0	1.82	1.63	0.18
200	1.81	1.64	0.17
1,000	1.83	1.64	0.19
2,000	1.87	1.64	0.22
3,000	1.90	1.66	0.24
4,000	1.94	1.68	0.26
5,000	1.99	1.68	0.30
6,000	2.05	1.66	0.39
7,000	2.08	1.64	0.44
8,000	2.04	1.59	0.45
9,000	2.08	1.64	0.45
10,000	2.11	1.65	0.46
11,000	2.20	1.67	0.53
12,000	2.19	1.67	0.52
13,000	2.19	1.69	0.50
14,000	2.11	1.68	0.44
14,450	2.15	1.67	0.48
14,550	2.17	1.66	0.50

6.0 REFERENCES

1. *ANFB Critical Power Correlation*, ANF-1125(P)(A) with Supplements 1 and 2, Advanced Nuclear Fuels Corporation, April 1990.

2. *Advanced Nuclear Fuels Corporation Critical Power Methodology for Boiling Water Reactors: Methodology for Analysis of Assembly Channel Bowing Effects*, ANF-524(P)(A) Revision 2, Supplement 1 Revision 2 and Supplement 2, Advanced Nuclear Fuels Corporation, November 1990.

3. *ANFB Critical Power Correlation Application to Co-Resident Fuel*, EMF-1125(P) Supplement 1, Appendix C, Siemens Power Corporation, November 1995.

4. Letter, A. C. Thadani (NRC) to J. S. Charnley (GE), "Acceptance for Referencing of Amendment 18 to General Electric Licensing Topical Report NEDE-24011-P-A, *General Electric Standard Application for Reactor Fuel*," May 12, 1988.

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