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ComEd

ESK-97-045

February 17, 1997

U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Document Control Desk

Subject: ComEd Response to Request for Additional Information on Topical Report EMF-96-051(P), "Application of Siemens Power Corporation ANFB Critical Power Correlation to Coresident GE Fuel for Quad Cities Unit 2 Cycle 15", NRC Docket No. 50-265

References:

1. "Request for Additional Information on Topical Report EMF-96-051(P), 'Application of ANFB Critical Power Correlation to Coresident GE Fuel for Quad Cities Unit 2 Cycle 15' (TAC No. M96213)", R. M. Pulsifer to I. Johnson, dated February 4, 1997.

2. "ComEd Response to NRC Staff Request for Additional Information (RAI) Regarding the Application of Siemen's Power Corporation ANFB Critical Power Correlation to Coresident General Electric Fuel for LaSalle Unit 2 Cycle 8 and Quad Cities Unit 2 Cycle 15 - NRC Docket No.'s 50-373/374 and 50.254/265", J. B. Hosmer letter to the U. S. Nuclear Regulatory Commission, dated July 2, 1996.

The Reference 1 transmittal requested ComEd to provide additional information with regard to Reference 2. Reference 2 is ComEd's request for NRC approval of the application of Siemens Power Corporation's ANFB critical power correlation to coresident GE fuel for Quad Cities Unit 2 Cycle 15.

The ComEd response to the Reference 1 request for additional information in regard to the document EMF-96-051(P) dated May 1996 is attached.

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AP01

Change: PDR Ltr 1 Encl 1 w/o prop

Please contact Gary Benes of the corporate Nuclear Licensing Staff at (630) 663-7282 if there are any further questions.

Respectfully,

E.S. Kraft, Jr.

E. S. Kraft, Jr.
Site Vice President
Quad Cites Station

Attachment: Response to Request for Additional Information-Application of the ANFB Critical Power Correlation to Coresident GE Fuel For Quad Cities Unit 2 Cycle 15

cc: A. B. Beach, Regional Administrator - RIII
R. M. Pulsifer, Project Manager - NRR
C. G. Miller, Senior Resident Inspector - Quad Cities
Office of Nuclear Facility Safety - IDNS
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Response to Request for Additional Information
Application of the ANFB Critical Power Correlation to Coresident GE Fuel for Quad Cities Unit 2 Cycle 15

Attachment Reference List:

1. ANFB Critical Power Correlation, ANF 1125 (P) (A), ANF-1125 (P) (A) Supplement 1, and ANF-1125 (P) (A) Supplement 2, dated April 1990.

2. "Request for EMF-524 (P) (A), Revision 2, Supplements 1 and 2 and ANF-1125 (PA (A), Supplements 1, and 2", H. D. Curet (SPC) letter to U. S. NRC Document Control, dated January 22, 1997, HDC:97-011.

3. "Acceptance for Referencing of Topical Report ANF-1125(P) and Supplement 1, 'ANFB Critical Power Correlation'", A. C. Thadani to R. A. Copeland, dated March 8, 1990.

4. "Implementation of the BWR ULTRAFLOW Spacer", R. A. Copeland to R. C. Jones, dated February 6, 1993, RAC:93:019.

5. September 20, 1990 letter form R. A. Copeland to L. E. Phillips, RAC:105:90.

6. November 14, 1990 letter from R. C. Jones (USNRC) to R. A. Copeland (SPC).

7. "Submittal of EMF-1125(P), Supplement 1 Appendix C", R. A. Copeland (SPC) to Director of Nuclear Reactor Regulation, dated November 30,1995, RAC:95:156.

8. "ComEd Response to NRC Staff Request for Additional Information (RAI) Regarding the Application of Siemen's Power Corporation ANFB Critical Power Correlation to Coresident General Electric Fuel for LaSalle Unit 2 Cycle 8 and Quad Cities Unit 2 Cycle 15 - NRC Docket No.'s 50-373/374 and 50.254/265", J. B. Hosmer letter to the U. S. Nuclear Regulatory Commission, dated July 2, 1996.

9. "Acceptance for Referencing of Amendment 18 to General Electric Licensing Topical Report NEDE-24011-P-A, General Electric Standard Application for Reactor Fuel", dated May 12, 1988.

10. Advanced Nuclear Fuels Methodology for Boiling Water Reactors, XN-NF-80-19 (P) (A) Volume 1 Supplement 3, Supplement 3 Appendix F, and Supplement 4, dated November 1990.

11. Commonwealth Edison Company Topical-Benchmark of CASMO/MICROBURN BWR Nuclear Design Methods, NFSR-0091, dated December 1991, Supplement 1 dated March 1992, and Supplement 2 dated May 1992, and associated NRC SER from C. P. Patel to T. J. Kovach dated March 22, 1993.

12. "Safety Evaluation for Topical Report EMF-96-021(P), Revision 1, 'Application of the ANFB Critical Power Correlation to Coresident GE Fuel for LaSalle Unit 2 Cycle 8' (Tac No. M94964)", D. M. Skay to I. Johnson, dated September 26, 1996.

Response to Request for Additional Information
Application of the ANFB Critical Power Correlation to Coresident GE Fuel
for Quad Cities Unit 2 Cycle 15

Requests for Additional Information:

1. **Provide the details of the development of the ANFB critical power correlation including experimental fuel database obtained from both Siemens Power Corporation (SPC) and other vendors.**

Response:

The ANFB critical power correlation was developed based on data from many different designs. The detailed description of the correlation, the data base used to develop the correlation, and the comparisons of the correlation to these data are provided in Reference 1. A copy of Reference 1 was recently provided to Dr. Huang of the NRC by H. D. Curet of SPC (Reference 2). This correlation was reviewed and approved by the NRC in March of 1990 (Reference 3).

As indicated in page 2 of the NRC SER of Reference 3, the ANFB database was "comprised of 2842 data points taken with 40 different test assemblies", and the correlation "applies to all ANF 8x8 and 9x9 designs to all GE standard and retrofit 8x8 designs and to all KWU BWR 9x9 fuel designs". (Note that ANF is the former company name for SPC). Section 3 of Supplement 1 of the report identifies the fuel rod array test sections used for the dryout measurements, including 4x4, 5x5, 9x9-5, 9x9 KWU, and 9x9-IX fuel rod arrays. Appendix B provides the specific dimensional data associated with each of these fuel rod arrays tested, while Appendix A documents the specific test data thermal hydraulic conditions, actual CPR from the tests, and analysis results. The number of data points for each test assembly along with the average CPR and standard deviation are presented at the end of each table in Appendix A.

Section 6 of Reference 1 additionally documents additive constants for a number of different designs, including GE 8x8s, SPC 8x8s, SPC/KWU 9x9s with water rods, and SPC/KWU 9x9s with an internal water box. Reference 4 documents the additive constants for the SPC 9x9 internal water box fuel design with the advanced ULTRAFLOW spacer which will be inserted into Quad Cities Unit 2 Cycle 15 with the previous cycle coresident GE fuel.

2. **Provide justification on the applicability of the ANFB critical power correlation to those fuel designs which are not part of the existing supporting database for the ANFB correlation.**

Response:

The formulation of the ANFB correlation separates the impact of assembly configuration/geometry into one correlation parameter--the additive constants. These additive constants are used to generate the F-effective values used in the correlation. The ANFB NRC approved topical report (Reference 1) also provides the methodology for developing the additive constants based on critical power determinations as a function of the thermal hydraulic conditions. Therefore, the application of the ANFB correlation to designs that were not initially part of the data base is demonstrated by developing appropriate additive constants.

This approach was used for the 9x9 internal canister design which was not part of the correlation data base. This approach was described to the NRC in Reference 5 and concurred with by the NRC in Reference 6. Specifically, the NRC response stated, "Since these additive constants were developed using methods previously reviewed and approved by the NRC in ANF-1125 (P) (A) and Supplements 1 and 2, we concur that additional NRC review is not required."

The document supplied to the Staff specifically for the application of the ANFB critical power correlation to coresident GE fuel for Quad Cities Unit 2 Cycle 15 (EMF-96-051 (P)) as well as the generic approval being requested by SPC in Reference 7 also makes use of this approach. Appropriate ANFB additive constants are determined for the coresident GE fuel based on comparisons of CPRs calculated with the approved GE GEXL critical power correlation and CPRs calculated with the ANFB correlation (resulting in the additive constants specified in Table 1.1). The response to Question 3 provides addition detail with regard to the CPR information upon which the ANFB vs. GEXL comparisons were based for the GE coresident fuel.

The associated total uncertainty in the ANFB correlation for the coresident GE fuel makes use of the component uncertainties associated with these critical power calculational comparisons and the uncertainty associated with the GE GEXL correlation relative to the GE measured dryout test database. This approach is identical to that submitted by ComEd and approved by the NRC (in the Reference 12 Safety Evaluation Report) for application of the ANFB critical power correlation to coresident GE fuel for LaSalle Unit 2 Cycle 8.

3. **Provide the detailed process, including criteria for rod pattern selection, to obtain the ANFB additive constants for GE9/10 fuel assemblies and the resultant additive constant uncertainty in Table 1.1 of the subject reference EMF-96-051(P). Also, provide experimental data to substantiate that Table 1.1 is also applicable to GE10 fuel assemblies.**

Response:

The additive constants were developed by SPC for the GE9/10 designs based on CPR calculations performed by ComEd with the GE GEXL critical power correlation and calculations performed by SPC with the ANFB critical power correlation.

ComEd provided SPC full core assembly-by-assembly CPR data calculated with the GE GEXL critical power correlation for various cycle exposures and core power/flow statepoints for cores consisting entirely of GE fuel (724 assembly data points for each full core calculation). These cycle exposures covered beginning, middle, and end of cycle conditions. The core power/flow conditions were selected non-realistically but conservatively such that artificially low flows were combined with typical power conditions, and artificially high power levels were combined with typical flow conditions to produce values for the CPR data over a wide range. These cycle exposure and core power/flow conditions produced localized conditions representative of many different assembly power distributions, including axially top peaked distributions. These calculations provided SPC with the local conditions corresponding to the CPR information calculated with the GE GEXL critical power correlation, including assembly flows and assembly power distributions. Hence, SPC had available the critical power of the GE9/10 fuel design as a function of the thermal hydraulic conditions.

SPC then evaluated these critical power conditions with the ANFB correlation using the same approved methodology as described in Reference 1. The ANFB correlation develops additive constants based on the fuel rod location within the assembly. The rod positions described in Section 2 of EMF-96-051 refer to these fuel rod locations within the fuel assembly. The additive constants for each fuel rod in the GE9/10 array are presented in Table 1.1 of EMF-96-051 using the layout of fuel pins across an assembly. These additive constants were generated using the procedure described in Supplement 1, Section 2 (starting on page 7) of Reference 1. With this approach, the cycle design information, including control rod patterns, is not directly utilized. The rod pattern information is considered in the safety limit methodology (through the distribution of assembly powers within the core). The safety limit methodology is unchanged.

The combination of the different cycle exposures used and the different core power/flow conditions resulted in the availability of ~11,900 individual assembly thermal hydraulic data points for ANFB vs. GEXL comparisons for the coresident GE fuel. However, not all of these points are used in the information presented in Figures 2.1 and 2.2 of EMF-96-051. Non-limiting information for peripheral fuel assemblies and high exposure low reactivity fuel assemblies were not included in the comparison database. Approximately 900 data points representative of the entire database were used in performing the CPR comparisons and generating the statistical information. The assembly power and flow conditions available from these data points covered a wide range. Assembly powers were on the order of ~4 to 9.5 MW, and assembly flows were on the order of ~0.4 to 1.5 $Mlb/hr/ft^2$.

As Figure 2.1 of EMF-96-051 indicates, the ANFB vs. GEXL CPR comparisons were performed for assemblies with a wide range of thermal hydraulic conditions, i.e. representative of CPRs near the safety limit (~1.0) up to higher CPR values on the order of 3.0. Additionally, Figure 2.2 uses the same CPR comparison data from Figure 2.1, but presents the difference in the ANFB and GEXL CPR calculations for the coresident GE fuel as a function of assembly exposure. The information in Figure 2.2 demonstrates the ANFB vs. GEXL CPR comparisons have the same degree of accuracy for low exposure as well as higher exposure coresident GE fuel. As indicated in the response to Question 6, the minimum assembly average exposure of the coresident GE fuel being inserted into Quad Cities Unit 2 Cycle 15 is ~11 Gwd/Mt. Therefore, only the comparison data above this exposure is germane for Cycle 15. Fuel assemblies with exposures greater than 25 Gwd/Mt (i.e. two or more cycles of operation) are of low reactivity and hence have CPRs much further away from the MCPR safety limit than much more reactive lower exposure fuel.

The additive constants that resulted from this process are applicable to both the GE9 and GE10 designs. The experimental data base that substantiates the applicability of the GE GEXL critical power correlation to the GE9 fuel design is discussed in Reference 9. SPC does not have access to any experimental measured dryout test data for the GE10 design. As discussed in pages 1-2 and 1-3 of EMF-96-051, CPR values for GE10 fuel will be higher (less limiting) than for GE9 fuel primarily due to the flow trippers providing improved mixing. Without consideration of the flow trippers, the GE9 vs. GE10 CPR performance would be the same due to the dimensions of the fuel, water rod, spacer and channel being identical internal to the fuel channel.

4. **Provide the database for the results shown in Table 2.1. Also, provide clarification that under what conditions the results shown in Table 2.1 indicate that ANFB predictions have a conservative bias relative to GEXL for GE9 fuel, and the reason for the same standard deviation between X and Y.**

Response:

Attached is a table containing the GEXL and ANFB critical power database shown in Figure 2.1 and used in determination of the statistics of Table 2.1 of EMF-96-051. As discussed in the response to Question 3, approximately 900 data points are represented in these Tables and Figure, covering a range of assembly powers on the order of ~4 to 9.5 MW and assembly flows on the order of ~0.4 to 1.5 Mlb/hr/ft^2.

The slight conservative bias of the ANFB correlation is demonstrated by examining the mean of the ratio of ANFB to GEXL comparisons. If this ratio was 1.0, there would be no bias between the correlations. If the ratio was greater than 1.0, it would indicate that the mean of the GEXL correlation predictions was more conservative than the mean of the ANFB correlation predictions. Because the mean was 0.974, the overall average of the ANFB predictions were 2.6% more conservative than the GEXL predictions. This ratio includes all of the comparisons and is intended to provide an overall estimate of the relationship between the correlations.

As indicated in the cover letter and Attachment 1 of Reference 8, Table 2.1 shown in EMF-96-051(P) has been updated. In the update, the second part of Table 2.1 has been removed to clarify the information. The reason that the standard deviation is the same for both expressions is that the expressions are two methods of presenting the same data. In the first method, the ratio of the correlations and that standard deviation is provided. In the second method, 1.0 minus the ratio of the correlations and the standard deviation is provided. The second method was to supplement Figure 2.2, while the first method was to supplement Figure 2.1.

5. **Please clarify that the total resulting standard deviation on page 3-2 of the subject reference is based on the correct equation of the combined uncertainty with respect to the request for additional information in the review of EMF-1125(P) Supplement 1 Appendix C.**

Response:

Attachment 1 of Reference 8 contains the updated equation and the results that are applicable to EMF-96-051(P). This is the revised equation that resulted from the NRC request for additional information in the review of EMF-1125(P) Supplement 1 Appendix C. Specifically, the MCPR Safety Limit calculations for Quad Cities Unit 2 Cycle 15 are based upon the updated uncertainties for the application of the ANFB critical power correlation to the coresident GE fuel which are based on the use of σtotal as 0.0703 (and not 0.048) and σadd as 0.038 (and not 0.026 as presented on page 3-2 of EMF-96-051(P)).

6. **Provide the description of the Quad Cities Unit 2 Cycle 15 fuel loading pattern including the types and number of the fuel assemblies. Also, provide the detailed approach for this cycle-specific analysis on the minimum critical power ratio, and provide the calculational procedures to generate the information in Table 5.1 including assumptions for the control blade pattern, actual core loading, actual bundle parameters, and full cycle exposure range.**

Response:

Throughout the cycle, and especially at EOC, the GE9/10 fuel will have significantly greater initial MCPR margin to the safety limit than for SPC fuel. Table 5.1 of EMF-96-051 was provided to illustrate this for the Quad Cities Unit 2 Cycle 15 core. The exposure in the Table corresponds to the cycle exposure and not a fuel assembly exposure. The Quad Cities core consists of 724 fuel assemblies. For each cycle exposure listed, the lowest CPR (based on the use of ANFB) of all of the SPC fuel in the core is listed. Also listed for each exposure is the lowest CPR (based on the use of GEXL) of all of the GE fuel in the core. Therefore, a larger MCPR for the GE fuel relative to the SPC fuel means that the lowest CPR of the GE fuel is further away from the safety limit than the lowest CPR of the SPC fuel. This inherent margin for the GE9/10 fuel combined with the conservative method of developing additive constant uncertainties ensures that the GE9/10 fuel will be non-limiting relative to the SPC fuel.

As noted in the report, the information provided in Table 5.1 of EMF-96-051 was generated based on the preliminary core configuration for Quad Cities Unit 2 Cycle 15 that was available in the second quarter of 1996. Since that time, the Cycle 15 core configuration plan has been refined to accommodate updated information relative to operation of Cycle 14 during the last half of 1996.

An updated Table 5.1 is enclosed which reflects this refined Cycle 15 projected loading pattern and operating characteristics. This updated Table 5.1 shows, for each cycle exposure, the lowest CPR of the fresh SPC fuel based on the use of the NRC approved ANFB correlation (Column B), and the lowest CPR of the GE fuel based on the use of the NRC approved GEXL correlation (Column C). The difference between these two columns (Column D) illustrates the amount by which the CPR of the GE fuel is further away from the safety limit than the SPC fresh fuel using the approved correlations. As stated on page 5-1 of EMF-96-051, the GE9/10 fuel will have more margin to boiling transition during potential transients. The updated Table 5.1 differs from the original Table 5.1 due to the revised number of SPC new fuel assemblies needed to meet the cycle energy requirements. The information in this Table 5.1 is generated for rated steady state nominal conditions with minor spectral shift operation (where the MCPR is expected to be the closest to the Safety Limit). As such, the data is generated for 100% core power and 98% core flow (which corresponds to 2511 Mwth and 96 Mlb/hr, respectively, for Quad Cities Unit 2) and rated pressure and subcooling (~1000 psia and ~22 btu/lbm). The sole purpose of the Table is to illustrate that the GE fuel operates at a higher MCPR than the SPC fuel, and therefore, has more CPR margin to the safety limit than the SPC fuel.

The information in Table 5.1 is generated with the use of the CASMO/MICROBURN-B codes as described in References 10 and 11. In using this detailed approach for the cycle specific analysis, the reactivity characteristics of each assembly design is determined with the CASMO lattice physics code. CASMO is used to model a horizontal plane through an assembly, and as such accounts for the different fuel pin enrichments, gadolinia concentrations, clad dimensions, water box dimensions, etc. CASMO produces nuclear physics data such as K∞, absorption and fission cross sections, power peaking, etc. The nuclear physics data generated with CASMO is individually applied to each fuel node within the core. A fuel node includes a 6" axial fuel assembly length in the vertical direction, and in the horizontal direction, includes the associated assembly fuel pins and fuel channel. These reactivity characteristics are then used by the MICROBURN reactor simulator code to determine power, void, and flow distributions within the reactor core (for each fuel node) at various core exposures throughout the cycle. The MICROBURN input model for the core being analyzed includes, in addition to the CASMO nuclear physics data, information on the assembly enrichment and exposure distribution within the core as well as the reactor operating parameters (such as core power, core flow, control rod pattern, etc.). The assembly thermal hydraulic conditions, as determined by the main program routines within the MICROBURN code, are used by additional program subroutines within MICROBURN to determine the CPR for each individual assembly within the core (i.e. 724 CPR values for each cycle exposure for the Quad Cities core) with either the ANFB or GEXL CPR correlations.

The Quad Cities Unit 2 Cycle 15 core is being licensed using the ANFB correlation for the coresident GE fuel.

The description of the anticipated Quad Cities Unit 2 Cycle 15 core is provided below:

Number of assemblies	Cycle First Loaded	Assembly design
216	15	SPC ATRIUM 9B
144	14	GE10
144	13	GE9B
152	12	GE9B
68	11	GE9B

Figures 1 and 2 (Enclosures 3 and 4) provide the refined beginning of cycle (BOC) and end of cycle (EOC) assembly average exposure distributions for Quad Cities Unit 2 Cycle 15. Since Quad Cities is not scheduled to shut down for refueling until March 1, 1997, the BOC exposure distribution still reflects a projection (with a high degree of accuracy) of the conditions at BOC 15. Cycle 15 is expected to have a full power energy capability of approximately 13 Gwd/Mt. The minimum assembly average exposure of the coresident GE fuel is projected to be approximately 11 Gwd/Mt at the beginning of Cycle 15.

Figure 3 (Enclosure 5) provides, on a quarter core basis, the location of the different SPC and GE assembly designs within the projected Quad Cities 2 Cycle 15 core.

Enclosure 6 provides the assumptions for the projected control rod pattern used to deplete Cycle 15 and generate the information in the updated Table 5.1.

Response to Request for Additional Information
Application of the ANFB Critical Power Correlation to Coresident GE Fuel
for Quad Cities Unit 2 Cycle 15

Enclosures:

1. GEXL and ANFB Critical Power Data for Figure 2.1 of EMF-96-051.
2. Updated Table 5.1 showing the lowest projected CPR for the SPC fresh fuel and GE coresident fuel.
3. Figure 1 - Quad Cities Unit 2 Cycle 15 Projected BOC Assembly Average Exposure Distributions.
4. Figure 2 - Quad Cities Unit 2 Cycle 15 Projected EOC Assembly Average Exposure Distributions.
5. Figure 3 - Quad Cities Unit 2 Cycle 15 Reference Loading Map.

Projected control rod patterns used to generate the information in the updated Table 5.1.

Response to Request for Additional Information
Application of the ANFB Critical Power Correlation to Coresident GE Fuel for Quad Cities Unit 2 Cycle 15

Updated Table 5.1

SPC Fuel and GE Fuel MCPR Data
for Quad Cities Unit 2 Cycle 15 Core Design

A	B	C	D
CYCLE EXPOSURE MWD/MT	LOWEST MCPR SPC FUEL	LOWEST MCPR FOR GE FUEL USING GEXL	DELTA MCPR GE-SPC
0	1.80	1.84	0.04
250	1.80	1.84	0.04
500	1.80	1.85	0.05
1000	1.79	1.86	0.07
1500	1.78	1.87	0.09
2000	1.77	1.89	0.12
2500	1.78	1.90	0.12
3000	1.78	1.92	0.14
3500	1.76	1.93	0.17
4000	1.76	1.95	0.19
4000	1.82	2.01	0.19
4500	1.80	2.01	0.21
5000	1.80	2.03	0.23
5500	1.79	2.04	0.25
6000	1.78	2.06	0.28
6500	1.79	2.08	0.29
7000	1.78	2.08	0.30
7500	1.78	2.08	0.30
8000	1.78	2.08	0.30
8500	1.78	2.09	0.31
9000	1.76	2.08	0.32
9000	1.71	2.06	0.35
9500	1.71	2.07	0.36
10000	1.71	2.08	0.37
10500	1.70	2.10	0.40
11000	1.70	2.09	0.39
11500	1.70	2.12	0.42
12000	1.73	2.12	0.39
12500	1.74	2.09	0.35
13000	1.79	2.15	0.36

Enclosure 1

GEXL and ANFB Critical Power Data for Figure 2.1 of EMF-96-051

(6 Pages)